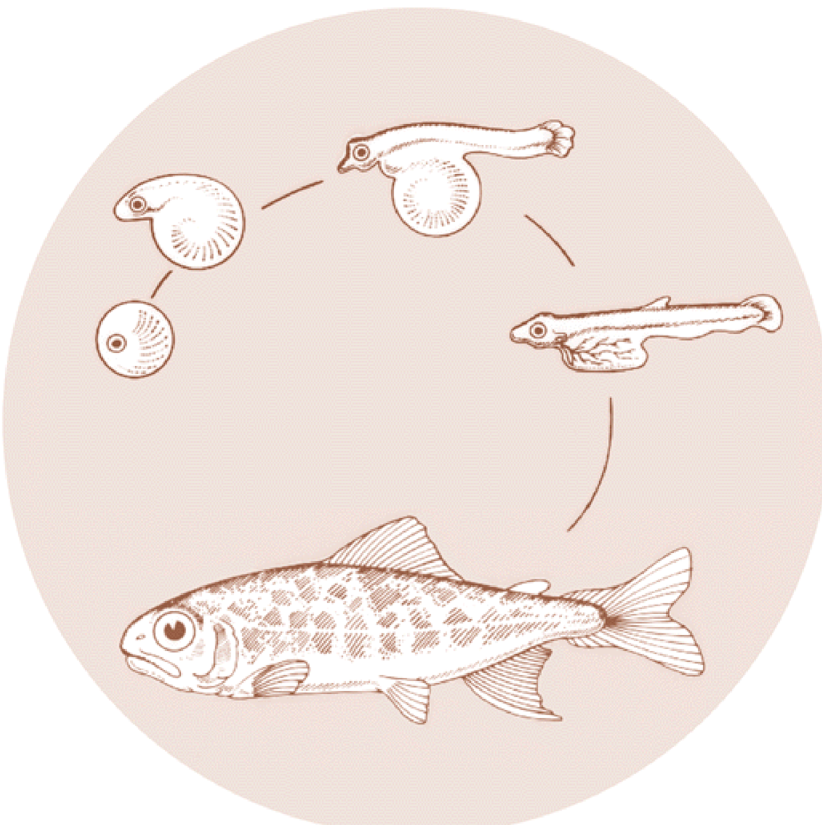
April 1991

SMOLT QUALITY ASSESSMENT OF SPRING CHINOOK SALMON

Annual Report



DOE/BP-97300-1

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

Waldo S. Zaugg, Dickhoff, W. W., Beckman, B. R., Mahnken, C. V. W., Winans, G. A., Newcomb, T. W., Coastal Zone and Estuarine Studies Division - National Marine Fisheries Service; Carl B. Schreck, Oregon Cooperative Fishery Research Unit - Oregon State University; Aldo N. Palmisano, Schrock, R. M., Wedemeyer, G. A., U.S. Fish and Wildlife Service; Richard D. Ewing, Oregon Dept. of Fish and Wildlife; C. W. Hopley, Washington Dept. of Fisheries; Smolt Quality Assessment of Spring Chinook Salmon, 1991, Annual Report to Bonneville Power Administration, Portland, OR, Contract DE-AI79-89BP97300, Project 89-046, 115 electronic pages (BPA Report DOE/BP-97300-1)

This report and other BPA Fish and Wildlife Publications are available on the Internet at:

http://www.efw.bpa.gov/cgi-bin/efw/FW/publications.cgi

For other information on electronic documents or other printed media, contact or write to:

Bonneville Power Administration
Environment, Fish and Wildlife Division
P.O. Box 3621
905 N.E. 11th Avenue
Portland, OR 97208-3621

Please include title, author, and DOE/BP number in the request.

SMOLT QUALITY ASSESSMENT OF SPRING CHNIOOK SALMON

Annual Report

Prepared by:

Waldo S. Zaugg
Walton W. Dickhoff
Brian R. Beckman
Conrad V. W. Mahnken
Gary A. Winans
Timothy W. Newcomb

Coastal Zone and Estuarine Studies Division
National Marine Fisheries Service

Carl B. Schreck

Oregon Cooperative Fishery Research Unit
Oregon State University

Aldo N. Palmisano
Robin M. Schrock
Gary A. Wedemeyer

U.S. Fish and Wildlife Service

Richard D. Ewing

Oregon Department of Fish and Wildlife

C. W. Hopley

Washington Department of Fisheries

Prepared for:

U.S. Department of Energy
Bonneville Power Administration
Environment, Fish and Wildlife
PO Box 3621
Portland, Oregon 97208

Project No. 89-046
Contract No. DE-AI79-89BP97300

April 1991

ABSTRACT

The physiological development and physiological condition of spring chinook salmon are being studied at several hatcheries in the Columbia River Basin. The purpose of the study is to determine whether any or several smolt indices can be related to adult recovery and be used to improve hatchery effectiveness. The tests conducted in 1989 on juvenile chinook salmon at Dworshak, Leavenwonh, and Warm Springs National Fish Hatcheries. and the Oregon State Willamette Hatchery assessed saltwater tolerance, gill ATPase, cortisol, insulin, thyroid hormones, secondary stress, fish morphology, metabolic energy stores, immune response, blood cell numbers, and plasma ion concentrations. The study showed that smolt development may have occurred before the fish were released from the Willsmette Hatchery, but not from the Dworshak, Leavenworth or Warm Springs I Hatcheries. These results will be compared to adult recovery data when they become available, to determine which smolt quality indices may be used to predict adult recovery.

The relative rankings of smolt quality at the different hatcheries do not necessarily reflect the competency of the hatchery managers and staff, who have shown a high degree of professionalism and expertise in fish rearing. We believe that the differences in smolt quality are due to the interaction of genetic and environmental factors. One aim of this research is to identify factors that influence smolt development and that may be controlled through fish husbandry to regulate smolt development.

CONTENTS

INTRODUCTION

Intensified efforts in areas of increased production, improvement of dam bypass systems, disease treatment and control, and transportation have not yielded the expected increase in adult returns of hatchery-reared spring chinook salmon (Oncorhynchus tshawytscha) to the upper- and mid-Columbia and Snake River Basins. Apparently other investigations must be included to find solutions to problems of dwindling returns. One useful investigation would be to determine the relation between adult contribution and the quality of fish released from the hatchery – – quality not only as it pertains to disease status or general health, but also as it relates to biological and physiological development. Are the fish released from hatcheries healthy as well as sufficiently developed biologically and physiologically to respond positively to their new stream and ocean environments so that survival will be maximal?

Reports on the relationship between smolt quality of hatchery-released salmonids and their survival to adulthood are scarce, but evidence is accumulating that suggests improvement in quality leads to increased numbers of recovered adults. Soivio and Virtanen (1985) reported correlations between return rates of Atlantic salmon (Salmo salar) and such smolt indices as migration readiness, energy stores, and body silvering, among others. Adult recoveries of fall chinook salmon appeared to be related to their migratory behavior after release as juveniles, and to development of certain aspects of smolt physiology (Zaugg 1989). Giorgi et al. (1988) reported that susceptibility of migrating juveniles to guidance by travelling screens at Columbia River dams may depend in part on the degree of smolt development. Seaward migration rates of juvenile spring chinook salmon doubled when release from the hatchery was delayed by 10 days (Parametrix, Inc. 1983). A more rapid migration translates to less exposure to predators and disease organisms and less competition with resident fish for natural food.

Thus, if there are benefits to releasing quality smolts, it becomes important to be able to quantitatively define a quality smolt. This study followed physiological development of spring chinook salmon at several hatcheries in the Columbia River Basin. The approach has been to test whether any or several monitored physiological parameters can be used to assess smolt quality, and whether this assessment can be related to adult recovery and used to improve hatchery effectiveness. Smolts were monitored at four hatcheries to assess the effects of variable husbandry techniques, treatments, environments, and gene pools. For example, the effect of rearing density on smolt quality indices was studied at one hatchery. Smolt indices in fish in adjacent raceways were examined at two hatcheries to provide a basis for generalizing from one raceway to the entire hatchery production. Minor objectives included evaluation of sampling, and the effect of crowding fish for sampling was examined at one hatchery.

METHODS

Tissue Collection

Field sampling of the 1987 brood spring chinook salmon at four hatcheries [Dworshak, Leavenworth, and Warm Springs National Fish Hatcheries (NFH) and Oregon State Willamette Hatchery] began in March 1989 and continued into May 1989. Four raceways (replicates) of production fish were sampled at Dworshak and Leavenworth NFH; two raceways of different densities were sampled at Warm Springs NFH (raceway 11 = 30,253 fish, low density; raceway 13 = 62,788 fish, normal density); and two release groups (April, raceway 21A and May, raceway 21B) were monitored at Willamette Hatchery. The same raceways were sampled each time. Three separate 15-fish samples were taken from each population; these samples were designated Groups I, II, and III (Appendix 1). All fish were measured and weighed to the nearest millimeter (mm) and gram (g). Fish sex was also determined, including an assessment of precocial development in males. The condition factor (body weight/fork length^3) was determined from length and weight data.

The 15 fish in Group I were obtained from the pond by dip net, and then stressed for 1 hour in a perforated bucket suspended in the raceway. Following the stress period, these fish were immersed in a lethal concentration (200 mg/L) of tricainemethanesulphonate (MS-222). After measuring and weighing, tails were severed at the caudal peduncle and blood was collected in heparinized Pasteur pipets. Plasma obtained from centrifuged samples was used to determine cortisol and glucose (see Appendix 1 for details).

The 15 fish of Group II were obtained from the pond by dip net, usually in two separate takes, and placed immediately in a lethal concentration of MS-22 Fish were measured and weighed, tails were severed at the caudaI peduncle and blood collected in heparinized tubes (microhemstocrit) or Pasteur pipets. Plasma obtained from centrifuged samples was used to determine cortisol, glucose, blood electrolytes, and plasma total protein. Anterior kidneys from these fish plus those from an additional five fish were taken for the immune competence assay. Blood from this group of fish was also used for microhematocrit determinations and for smears.

The 15 fish of Group III were secured with the dip net and held alive in a bucket. One fish at a time was removed, killed by a blow to the head, measured, weighed, and photographed for morphometric analysis. Blood was taken and plasma obtained as indicated above. Plasma was used for thyroxine (T4), triiodothyronine (T3), and insulin determinations. A ventral incision was then made, sex noted, and a section (0.1 to 0.2 g) of the lower lobe of the liver removed, weighed to the nearest 10 mg, and frozen immediately with liquid nitrogen; the liver tissue was used later for measuring glycogen content. A second piece of liver was excised and placed in a tube on dry ice for later liver triglyceride analysis. A section of skin (1 x 5 cm) in the area between the lateral line and the dorsal fin was removed, frozen on dry ice, and used later for measuring skin guanine content. After removal of the skin, a section (0.1 to 0.2 g) of white muscle was removed, weighed to the nearest 10 mg, placed on dry ice, and used later for measuring tissue water content. Filaments were trimmed from the lower half of two to four gill arches and placed in a tube with 1 ml of a sucrose-ethylenediaminetetraacetic acid-imidazole (SEI) solution. The tube was capped, placed on dry ice, and used later for measuring adenosine triphosphatase (ATPase) activity. Fish were inspected for gross kidney lesions and liver condition.

Analytical Procedures

Crowded vs. Uncrowded Samples

After sampling two raceways at the Leavenworth NFH in the normal manner by dip net, the water level was lowered approximately 50%. Fish were crowded by block seine into the downstream 4 m of the raceway and three random dips (about 150 fish per dip) were taken and placed in a one-quarter sampling net contained in a tub. One fourth of these fish were placed in a plastic barrel containing 80 L of water. Fifteen fish (as in Group II above) were immediately dipped randomly from the barrel and placed in a lethal concentration of MS-222, and processed for plasma collection (for later cortisol analysis), hematocrits, and blood smears. An additional 15 fish (as in Group III above) were randomly netted, photographed (for morphometric analysis), processed for plasma, liver, skin and muscle collection (for later analysis of T4, T3, insulin, liver glycogen, liver triglyceride, skin guanine, and gill ATPase activity). A stress challenge (as in Group I above) was not performed. Fish remaining in the plastic barrel (about 60) were anesthetized and measured to obtain length frequency data. For additional details, see Appendix 1.

Saltwater Challenge

Groups of 20 fish each were placed for 24 hours in salt water of 30 parts per thousand (°/oo) Instant Ocean[1] artificial sea salts. After the challenge period, fish were removed, weighed, and measured. Blood for plasma sodium and potassium (Clarke and Blackburn 1977) and gill filaments for ATPase analyses were taken as described in Appendix 1.

Gill ATPase Activities

Gill filaments were trimmed from arches and preserved in SEI at –80° C until analyzed for Na^{+}–K^{+} ATPase activity as described in Appendix 1 and Zaugg (1982). Units of activity are μmoles P_i/mg protein-hour.

Thyroxine (T4) and Triiodothyronine (T3)

Blood plasma concentrations of thyroid hormones were analyzed by radioimmunoassay (RIA) according to methods described by Dickhoff et al. (1978, 1982b).

Plasma Insulin

Blood plasma concentrations of insulin were analyzed by a homologous RIA according to the method described by Plisetskaya et al. (1986).

Plasma Cortisol, Baseline and Stressed

Blood plasma concentrations of cortisol from stressed and unstressed fish were measured by RIA according to the method of Redding et al. (1984).

Stress Challenge

This stress challenge test was described by Barton et al. (1985). Fish were netted and subjected to an acute handling stress in the raceways by suspending them for 1 hour in a perforated bucket such that the backs of the median-sized fish were just under the surface

---

1 The usc of trade names does not imply cndorscmcnt by the National hlarinc Fishcrics Scrvicc. NOAA.

of the water. The fish were then anesthetized, and a blood plasma sample was taken for later analysis for conisol and glucose content.

Plasma Glucose

Blood glucose concentrations were determined by a calorimetric procedure (Sigma Chemical Co., St. Louis MO).

Liver Glycogen

Liver glycogen was measured according to the method of Wedemeyer and Yasutake (1977). Glycogen is extracted into potassium hydroxide, precipitated, hydrolyzed to glucose, and quantified with a glucose hexokinase enzymatic determination, measured by spectrophotometry at 340 nm.

Liver Triglyceride

Liver triglyceride concentration was determined according to the following method. Liver samples were homogenized in water and centrifuged. Triglyceride concentrations were measured by the enzymatic method of Bucolo and David (1973). Glycerol is stripped by phospholipase C and then reduced with glycerol dehydrogenase. The reduced nicotine adenine dinucleotide (NADH) generated is oxidized by para-iodo-nitro-tetratzolium violet, mixed with enzymes and measured by spectrophotometry at 500 nm.

Morphometrics

Morphometric distances for 26 truss-network characters were calculated from each photograph and analyzed by principal component (PC) analysis (Winans 1984, Winans and Nishioka 1987).

Skin Guanine

Skin guanine content as a quantitative measure of silver coloration was determined according to the method of Staley (1984). Skin samples were extracted with 1 N HCI for 48 hours at 21° C. Extracts were adjusted to pH 8.1 and treated with xanthine oxidase and guanase for 2 hours at 21° C. Guanine concentration was measured by spectrophotometry at 290 nm.

Muscle Water

Water content of dorsal muscle was determined according to the method of Wedemeyer and McLeay (198 1).

Blood Electrolytes

Blood plasma Na+ and K+ concentrations were determined by flame photometry; blood plasma Cl- concentrations were determined using a chloridometer.

Plasma Total Protein

Plasma total protein was determined using a refractometer calibrated to distilled water.

Blood White Cell Count and Differential White Cell Count

White cell counts were performed to determine the number of white cells per hundred red cells, and to differentiate the number of lymphocytes, neutrophils, and monocytes in 100 white cells according to the method of Wedemeyer and Yasutake (1977).

Immune Response

The immune response of fish was determined by assessing the production of anterior kidney antibody-secreting cells [plaque-forming cells (PFC)] after in vitro exposure to a synthetic antigen (n-initrophenol-lipopolysaccharide) Vibrio anguillarum according to the method of Tripp et al. (1987).

RESULTS

Crowded vs Uncrowded Samples

To resolve the question whether dip-netting fish from an uncrowded raceway obtained appropriate samples for this study, fish collected in two separate raceways under both crowded and uncrowded conditions were compared. This was done at Leavenwonh NFH during 12-14 April 1989. The means and standard deviations of all measurements are shown in Table 1. Since in the routine sampling there was not sufficient blood available from individual fish for all measurements indicated in Table 1, samples from two groups of 15 fish each were processed separately for gill ATPase, hematocrits, thyroid hormones (T4 and T3), and conisol. The data on fork length, body weight, and condition factor were pooled.

No significant differences [analysis of variance (ANOVA), Fisher exact test of protected least significant difference (PLSD); $P < 0.05$ (Zar 1974)] were obsemed b etween the two groups comparing data on fork length, body weight, condition factor, hematocrit, gill ATPase activity, plasma T3 , plasma protein , morphometrics, liver glycogen, muscle water, liver triglyceride, skin guanine, plasma Na^{+}, plasma Cl-, plasma K^{+}, white cell count, lymphocytes, and neutrophils. The values for plasma T4 and cortisol concentration of the crowded fish in both raceways were significantly higher than those of the uncrowded fish in corresponding raceways. These differences in T4 and conisol may be due to differences in the time of day when the fish were sampled, since both of these hormones may show diurnal variation in their plasma levels (Eales et al. 1981, Laidley and Leatherland 1988). The uncrowded fish were sampled in the late morning (raceway 32) and late afternoon (raceway 45); the crowded fish were sampled from early (raceway 42) to mid-morning (raceway 45). Furthermore, it might be predicted that cortisol levels would be higher in the crowded fish compared to uncrowded fish since the additional disturbance during crowding may cause stress-related increases in cortisol secretion.

In summary, the sampling of crowded fish gives results equivalent to sampling uncrowded fish for all of the measurements in this experiment. When variation is observed, it may be predicted due to the timing (morning vs afternoon) or stressful nature of the sampling. We concluded that dip netting of uncrowded fish is an appropriate method for obtaining a sample of the fish in the raceway, and no significant advantage is afforded by sampling crowded fish.

Table l.-- Comparison of means and standard deviations (in parentheses) among all measurements from fish sampled under crowded and uncrowded conditions at Leavenworth National Fish Hatchery. After sampling two raceways in the normal fashion (by random dip net), fish were crowded into the tail end of the raceway and sampled again using a one-quarter sampler. Asterisks indicate statistically significant differences ($P < 0.05$; ANOVA) between values for crowded and uncrowded fish within a raceway .

		Crowded		Uncrowded	
Measurement	n	Raceway 42	Raceway 45	Raceway 42	Raceway 45
Fork length (mm)	30	124 (16)	124 (12)	133 (15)	127 (13)
Weight(g)	30	22.9 (10.9)	23.0 (8.6)	27.4 (10.0)	23.8 (7.5)
Condition factor	30	1.141 (0.06)	1 .183 (0.052)	1.124 (0.056)	1.137 (0.051)
Hematocrit (%)	15	36 (5)	37 (3)	34 (7)	37 (4)
Gill Na^+–K^+ ATPase	15	10.0 (2.0)	10.9 (2.5)	10.1 (2.8)	11.3 (2.3)
Plasma T4 (ng/ml)	15	12.6 (2.6)*	15.2 (4.4)*	5.5 (1.1)	9.2 (4.2)
Plasma T3 (ng/ml)	15	6.3 (1.5)	6.4 (1.5)		6.8 (2.3)
Plasma cortisol (ng/ml)	15	14.7 (3.5)*	8.6 (3.2)*	9.3 (7.1)	3.0 (1.8)
Plasma protein (g/dL)	15	4.4 (0.8)	5.1 (1.2)	4.1 (0.8)	4.6 (0.8)
Morphometrics (PC)	15	0.136 (0.979)	0.464 (0.750)	0.0189 (0.641)	-0.078 (1.09 1)
Liver Glycogen (g·%)	15	1.77 (0.20)	1.51 (0.09)	1.64 (0.19)	1.38 (0.16)
Muscle water (%)	15	21.6 (1.5)	20.3 (0.8)	21.3 (1.1)	20.7 (0.8)
Liver triglyceride (mg/g)	15	9.69 (1.73)	7.02 (2.12)	9.01 (2.42)	8.57 (1.39)
Skin guanine (mg/g)	15	23.82 (4.80)	27.29 (4.40)	22.83 (5.32)	25.09 (4.63)
Plasma Na^+ (mM)	15	150.6 (3.1)	15 1.2 (2.7)	153.3 (1.9)	151.0 (2.3)
Plasma Cl^- (mM)	15	128.9 (9.2)	126.4 (3.5)	133.7 (2.7)	119.7 (3.9)
Plasma K^+ (mM)	15	4.83 (1.5)	5.49 (1.5)	4.36 (1.8)	5.64 (1.0)
White cell count (WCC)(%)	15	0.5 (0.3)	0.8 (0.3)	0.7 (0.3)	0.6 (0.3)
Lymphocytes (% WCC)	15	94 (3)	96 (3)	94 (3)	93 (3)
Neutrophils (% WCC)	15	6 (3)	4 (3)	6 (3)	7 (3)

Comparison of Spring Chinook Salmon at Columbia River Hatcheries

Length and Weight Comparisons

The fork lengths were determined for sampled fish (see Appendix 1). For concise description of the relationships, representative data from sampling Group III at the four hatcheries are shown in Figure 1. The mean fork lengths of the fish sampled at Leavenworth (raceways 42-49), Dworshak (raceway 1 l), and Warm Springs (raceway 11) Hatcheries were most often in the range of 120 to 140 mm throughout the sampling period. In contrast, mean fork lengths of fish sampled at the Willamette Hatchery (raceway 2 1 B) were in the range of 150 to 170 mm. This trend of larger fish at the Willamette Hatchery was apparent in all sampled groups (Appendix 1).

Average body weights of the fish from sample Group III are shown in Figure 2. Mean body weights of the groups at Leavenworth, Dworshak, and Warm Springs Hatcheries were in the range of 20 to 35 g throughout the sampling period. Mean body weights of fish at Willamette Hatchery ranged from 40 to 60 g. In comparison with the other hatcheries, greater body weight was evident for all Willamette fish (Appendix 1).

Both the fork length and body weight data indicate that the fish at the Willamette Hatchery were larger than fish at the other three hatcheries. Some of the fish at the Willamette Hatchery were released at a later date (May) than those at the other hatcheries (April). However, the greater size of the Willamette fish was observed in March, and this relationship was maintained throughout the sampling period (Figs. 1 - 2).

The condition factors of sampled fish were calculated from length and weight data (Appendix l), and are shown in Figure 3. The data shown in Figure 3 were derived from the data shown in Figures 1 and 2. The mean condition factor increased in all fish either during March or from March to April. A marked decrease in condition factor was observed for the Willamette fish sampled between the end of April and the beginning of May.

In summary, the data on fork length, body weight, and condition factor indicate that the fish at Willamette Hatchery were larger than those at the other three hatcheries throughout the period of sampling. The greater decline in condition factor at the time of release of the May group at Willamette Hatchery suggests that these fish may have been the most developed of all fish sampled at the time of release from the hatcheries. A decrease in condition factor is the expected observation for fish undergoing smoltification (Folmar and Dickhoff 1980; Hoar 1988).

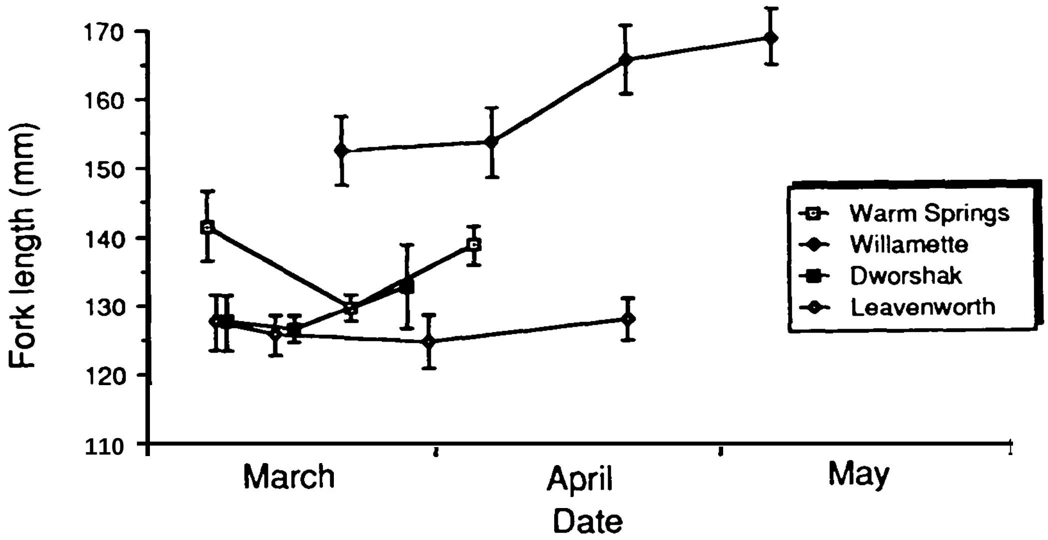


Figure 1.--Mean fork lengths of fish sampled (Group III) at the four hatcheries indicated. Brackets indicate ± one standard error.

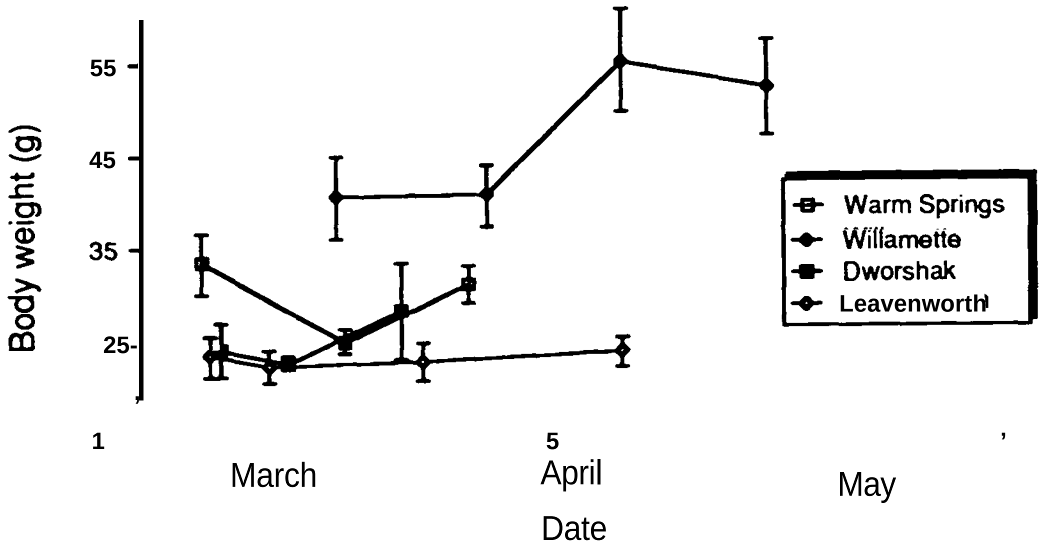


Figure 2.--Mean body weights of fish sampled (Group III) at the four hatcheries indicated. Brackets indicate + one standard error. Data from the same fish shown in Figure 1.

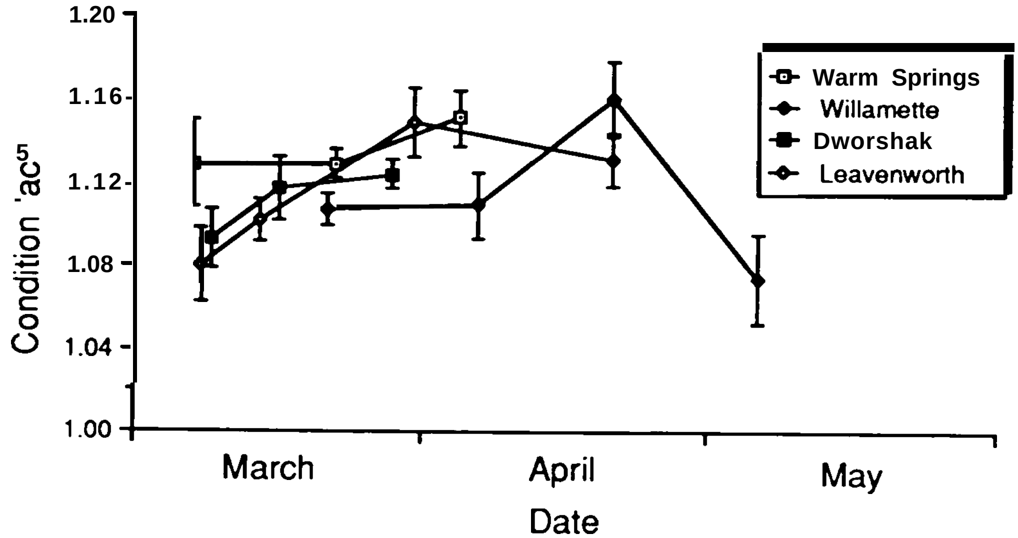


Figure 3.--Mean condition factors of fish sampled (Group III) at the four hatcheries indicated. Brackets indicate ± one standard error. Data from the same fish shown in Figure 1.

Saltwater Challenge Test

Saltwater challenge tests were performed shortly before release of the fish from the hatcheries (also 1 month before release at Leavenworth and Willamette Hatcheries). Samples were taken to determine plasma sodium and potassium concentrations for the control and saltwater-challenged fish at 24 hours after transfer to salt water. Gill ATPase activities were also determined for saltwater-challenged fish. Plasma sodium concentrations and mortalities after saltwater challenge of fish from all hatcheries tested are shown in Figure 4.

Plasma sodium concentrations from all control fish (not exposed to salt water) were below 170 mmol/L, whereas all test groups at 24 hours after saltwater entry had sodium levels above 200 mmol/L. Of the fish transferred to salt water, the highest mean sodium levels were observed in fish from Dworshak Hatchery; the lowest mean sodium levels were observed in fish from Willamette Hatchery. These results suggest that the fish from the Willamette Hatchery developed the greatest saltwater tolerance at the time of release. However, published work on plasma sodium concentrations of fully smolted chinook salmon subjected to seawater challenge indicates that levels should remain below 170 mmol/L (Blackbum and Clarke 1987). This suggests that none of the groups of fish tested in our study were fully smolted, since mean plasma sodium concentrations exceeded 200 mmol/L in all groups. On the other hand, in comparison with published studies, the plasma sodium concentrations measured in fish either in salt water or in fresh water are unusually high. An alternative interpretation of these data on plasma sodium is that there may have been some contamination of the blood samples with glassware used at the time of sampling. In support of this possibility of contamination of the plasma samples are our own data on plasma sodium concentrations measured for fish that were in fresh water and were not part of the saltwater challenge. The sodium values for the routinely-sampled fish in fresh water (Group II) were between 150 and 155 mmol/L (see below), whereas the sodium values for the freshwater control fish in the saltwater-challenge experiment, which were sampled using different glassware than for Group II, were 168, 165, 165, and 152 mmol/L for fish from Leavenworth, Dworshak, Willamette, and Warm Springs, respectively. Regardless of the overall high values for plasma sodium in the saltwater challenge. the data are useful for comparisons between hatcheries within the 1989 study, assuming that possible contamination of the samples was uniform in all groups.

A few fish died during the saltwater challenge test (Fig. 4). In the 29 March test at Leavenworth, four fish died during the 24-hour period in saltwater, seven fish died during

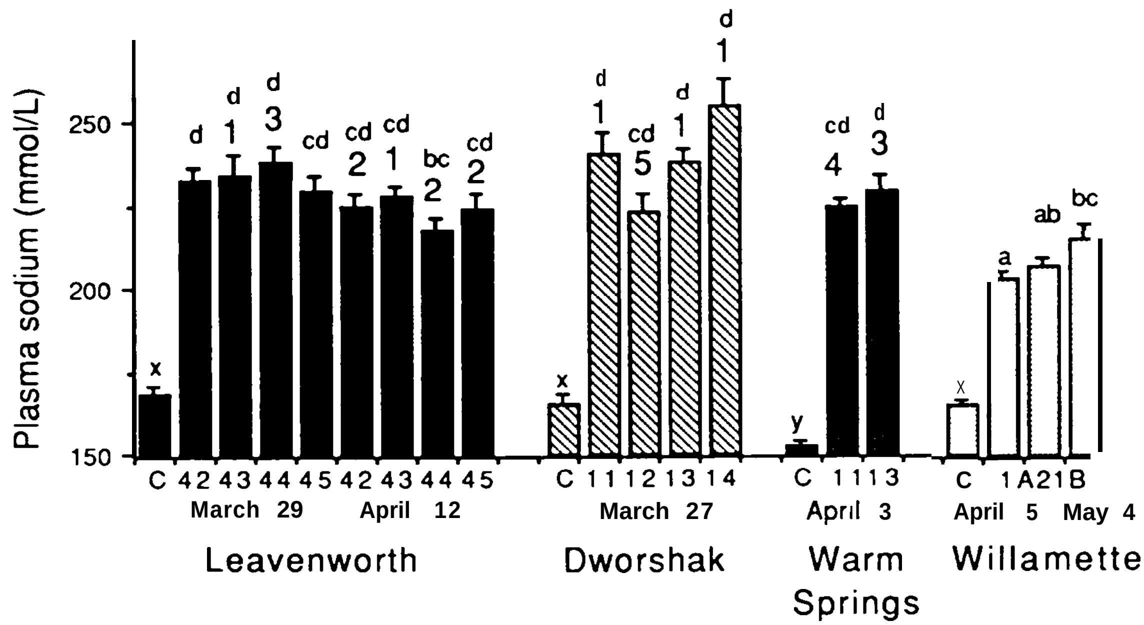


Figure 4.--Mean plasma sodium values for control and saltwater challenged fish from each hatchery. Brackets indicate + one standard error. The letter or number below each column represents control (C) or the raceway number. The number above each bar indicates the number of fish mortalities in that group after the 24-hour period in salt water. The letters above each bar indicate significant differences ($P < 0.05$; ANOVA, Fisher PLSD) in the sodium values. Bars with a common letter are not significantly different. N = 15 to 20 fish per bar.

the 12 April test at Leavenworth; eight fish died in the test on 27 March at Dworshak, and seven fish died during the 3 April test at Warm Springs. In conuast, no fish died at any time during the saltwater challenge tests at Willamette. The incidence of fish mortality is approximately correlated with elevated plasma sodium concentrations in fish at Leavenworth, Dworshak, and Warm Springs Hatcheries.

Plasma potassium concentrations and mortalities after saltwater challenge of fish from all hatcheries tested are shown in Figure 5. The expected result would show that smolts have greater capacity for potassium regulation than parr, although potassium regulation is more variable than sodium regulation in saltwater-challenged fish (Blackbum and Clarke 1987). Most of the test fish at Leavenworth Hatchery had plasma potassium concentrations significantly elevated over that of controls. At all other hatcheries, there were usually no significant differences in plasma potassium between control and treated fish. The potassium values were generally lower in fish from Dworshak, Warm Springs, and Willamette Hatcheries compared to fish from Leavenworth Hatchery. These data suggested that fish at Leavenworth Hatchery were less able to control their plasma potassium levels in comparison to fish at the other hatcheries, which appeared comparable in their capacity for potassium regulation during saltwater challenge. The plasma potassium values for the freshwater controls in the saltwater challenge test were generally higher than those for fish in Group II during routine sampling of production fish (see below). This difference supports our suspicion that the plasma samples from the saltwater challenged fish were slightly contaminated with salt water.

Gill Na+-K+ATPase activities of fish after saltwater challenge are shown in Figure 6. The lowest gill ATPase activities were in fish tested during late March at Leavenworth and Dworshak Hatcheries. The highest activities were found in fish from Willamette Hatchery, particularly those from raceway 21B tested on 4 May. The high ATPase values of fish at Willamette hatchery, their lower plasma sodium (Fig. 4). and their good survival in the saltwater challenge test are suong indicators of good saltwater tolerance of these fish.

Gill ATPase Activity in Fish in Fresh Water

The patterns of gill Na+-K+ ATPase activity for groups of fish at the different hatcheries are shown in Figure 7. The mean gill ATPase activities remained below 15 µmoles Pi/mg protein-hour in all groups at the Dworshak, Leavenworth, and Warm Springs Hatcheries throughout the sampling period; there were no statistically significant differences in any of the groups sampled at these hatcheries. Higher ATPase activities were observed in the two groups of fish at the Willamette Hatchery. Significant increases in ATPase occurred

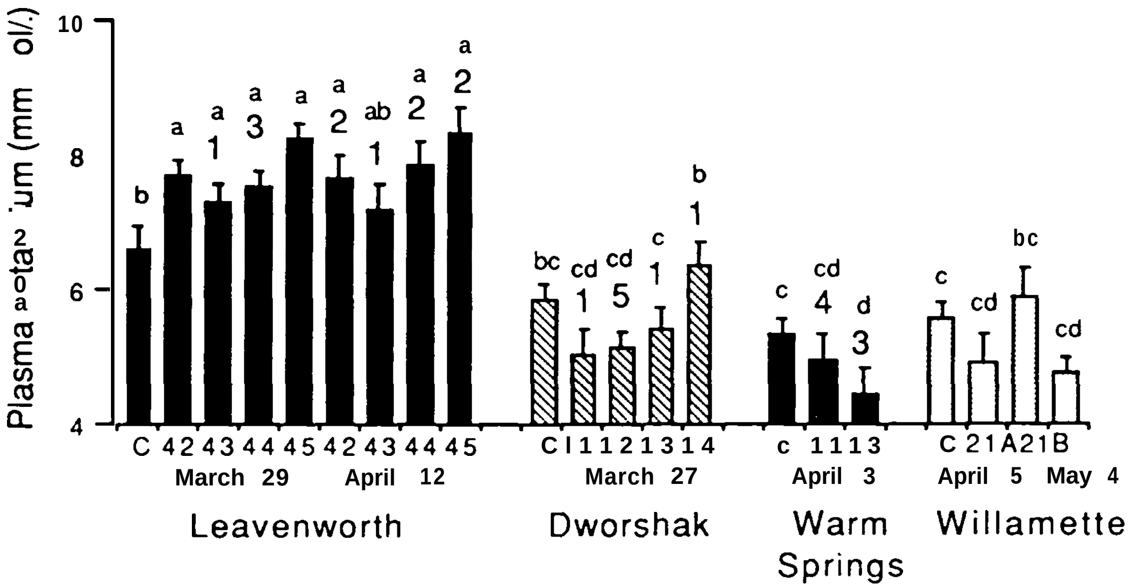


Figure 5.--Mean plasma potassium values for control and saltwater-challenged fish from each hatchery. Brackets indicate + one standard error. The letter or number below each column represent conuol (C) or the raceway number. The number above each bar indicates the number of fish mortalities in that group after the 24-hour period in seawater. The letters above each bar indicate significant differences ($P < 0.05$; ANOVA, Fisher PLSD) in the potassium values. Bars with a common letter are not significantly different. N = 15 to 20 fish per bar.

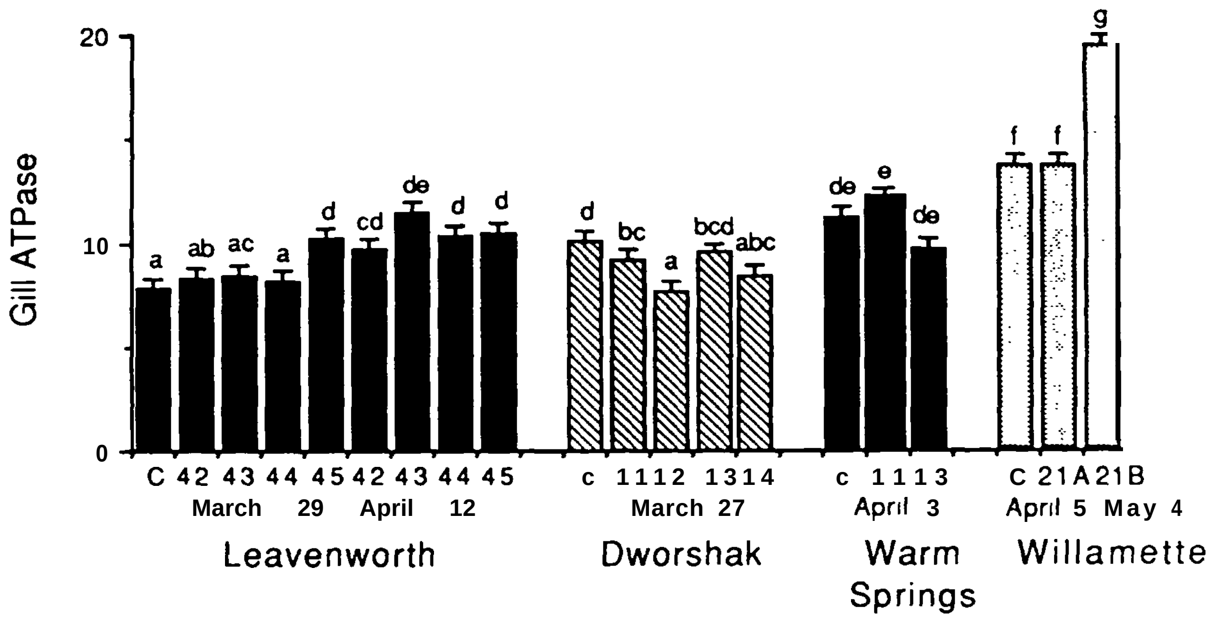


Figure 6.--Mean gill Na+-K+ ATPase values for control and saltwater challenged fish from each hatchery. Gills were sampled after the saltwater challenge. Brackets indicate + one standard error. The letter or number below each column represent control (C) or the raceway number. The letters above each bar indicate significant differences ($P < 0.05$; ANOVA) in the values. Bars with a common letter are not significantly different. N = 15 to 20 fish per bar.

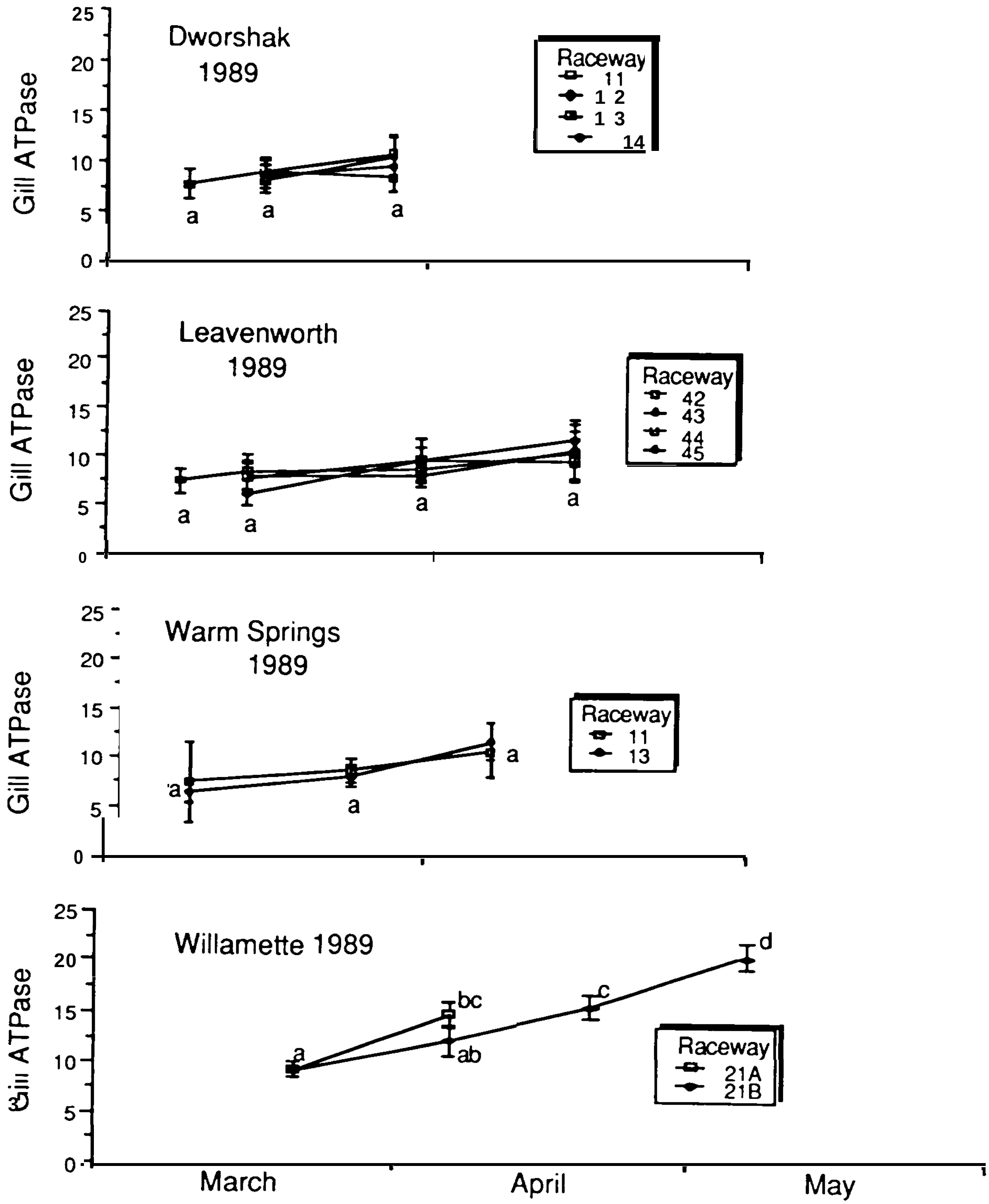


Figure 7.--Gill Na^{+}-K^{+} ATPase activities (µmoles P_i/mg protein-hour) for groups of fish sampled at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Letters next to the symbols indicate significant differences within a hatchery ($P < 0.05$; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

between March and April in the April release group (raceway 2 1A). For the May release group (raceway 2 1 B), significant increases in ATPase were observed during April and May. The May release group at Willamette Hatchery showed the highest ATPase activity at the last sampling date. Since smolting is associated with high ATPase activity (Zaugg and McLain 1972), these data suggested that the greatest smolt development was attained by the May release group at the Willamette Hatchery. In contrast, little or no smolt development was indicated by ATPase activities measured in the groups at the other hatcheries. At the time of release of fish in Dworshak, Leavenworth, and Warm Springs Hatcheries, the mean gill ATPase activities were in the range of 10 to 12 µmoles Pi/mg protein-hour. At the time of release of fish at Willamette Hatchery, mean gill ATPase activities were 14.2 (April release) and 19.8 (May release) µmoles Pi/mg protein-hour.

Plasma Hormone Concenuations

Plasma concentrations of thyroid hormones, insulin, and cortisol are shown in Figures 8 through 11 for fish sampled at the different hatcheries.

The plasma concentrations of thyroid hormones, thyroxine (T4) and triiodothyronine (T3), are shown in Figures 8 and 9, respectively. The mean levels of T4 showed an increasing trend in most fish sampled at the Dworshak Hatchery. There was a small but significant peak in plasma T4 occurring in mid-March in fish in raceway 14 at Dworshak. At Leavenworth Hatchery, the initial sample (7 March) was from raceway 49. Subsequently, the mean T4 levels co-varied in pairs of raceways; values from raceways 42 and 43 were similar and higher than those from raceways 44 and 45 on 14 and 29 March. On the last sampling date, 14 April, T4 values from raceways 44 and 45 were similar and higher than those from raceways 42 and 43. This pattern of variation was probably due to differing times of the day when the blood samples were taken. Raceways 42 and 43 were sampled in the afternoon on 14 and 29 March, whereas they were sampled in the morning on 14 April. Raceways 44 and 45 were sampled in the morning on 14 and 29 March, whereas they were sampled in the afternoon on 14 April. Daily fluctuations in T4 levels in salmonids are well-known (Eales et al. 1981; Laidley and Leatherland 1988). For the Leavenworth fish, however, there was a decreasing trend in T4 levels. At Warm Springs Hatchery, T4 levels were initially high in both groups; levels declined significantly in the subsequent samples. It was noted at the time of the first sampling at Warm Springs that the hatchery water was unusually silted. A large amount of silt had just appeared in the water at the time the sampling crew arrived at the hatchery. If the fish sensed this siltation as novel fresh water, then the relatively high T4 levels measured in the first sampling point at

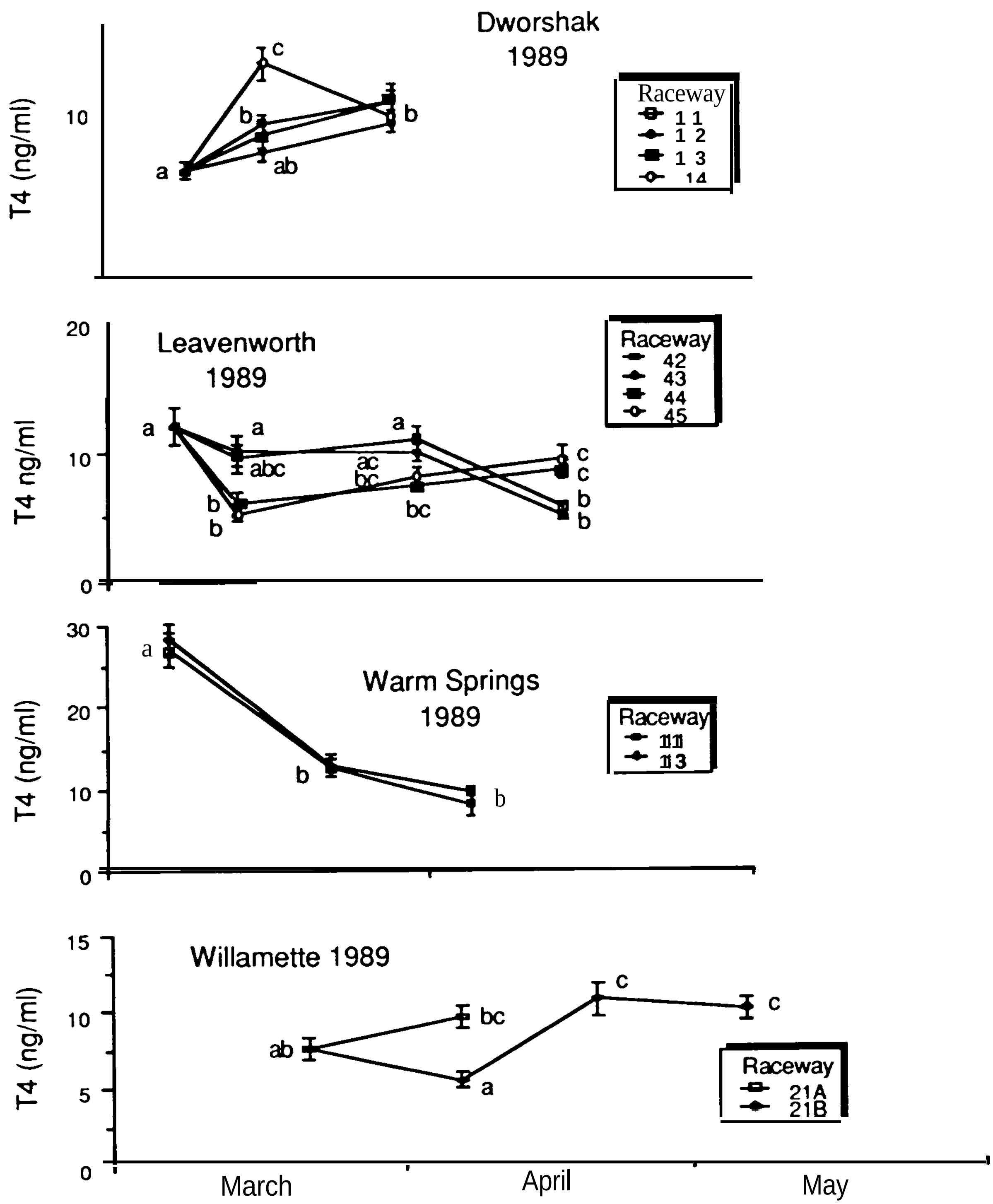


Figure 8.--Plasma concentrations of thyroxine (T4) in sampled fish at the indicated hatcheries. Symbols indicate means; buckets indicate +_ one standard error. Letters next to the symbols indicate significant differences within a hatchery (P < 0.05; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

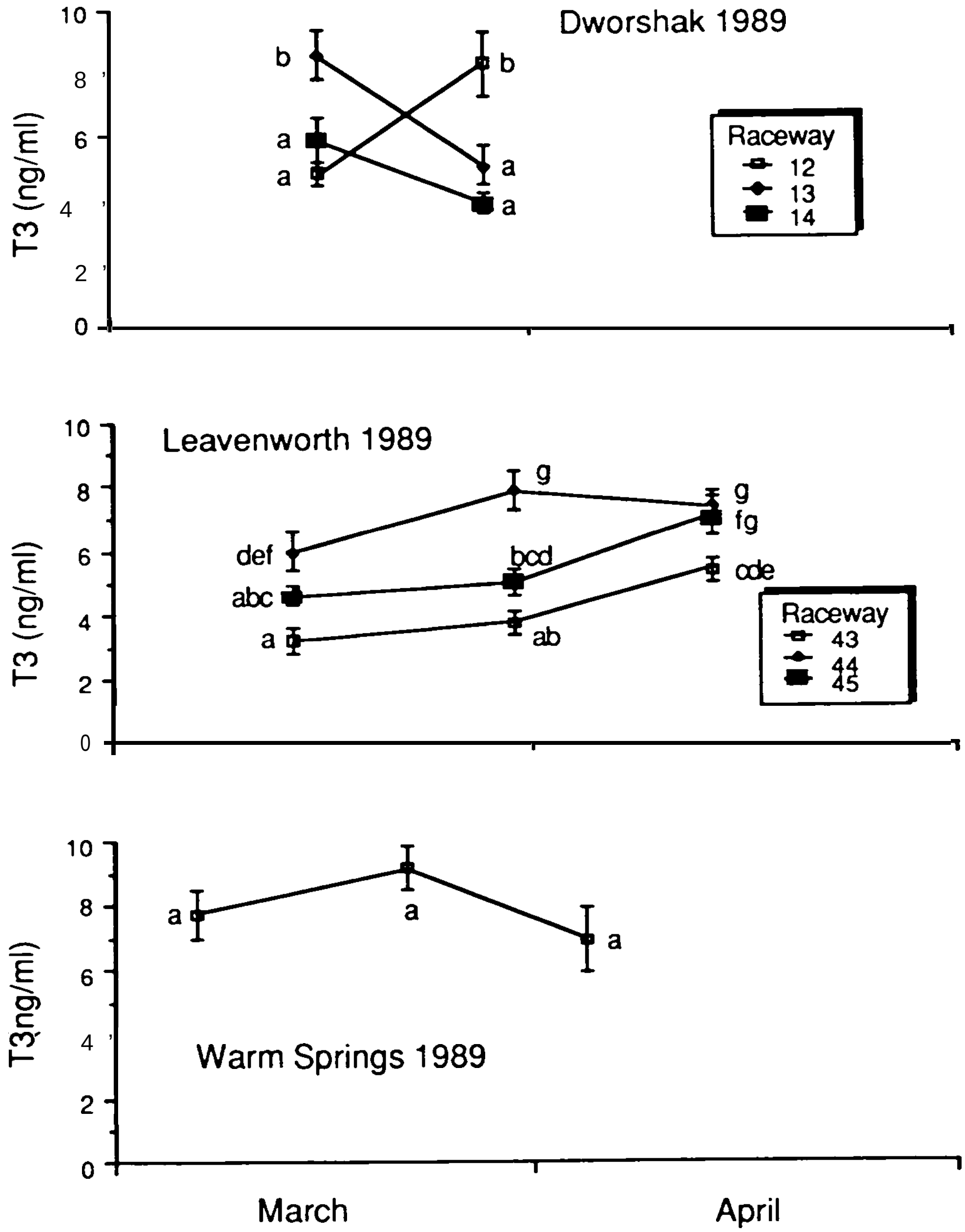


Figure 9.--Plasma concentrations of triiodothyronine (T3) in sampled fish at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Data for Willamette Hatchery are reported in the text. Letters next to the symbols indicate significant differences within a hatchery ($P < 0.05$; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

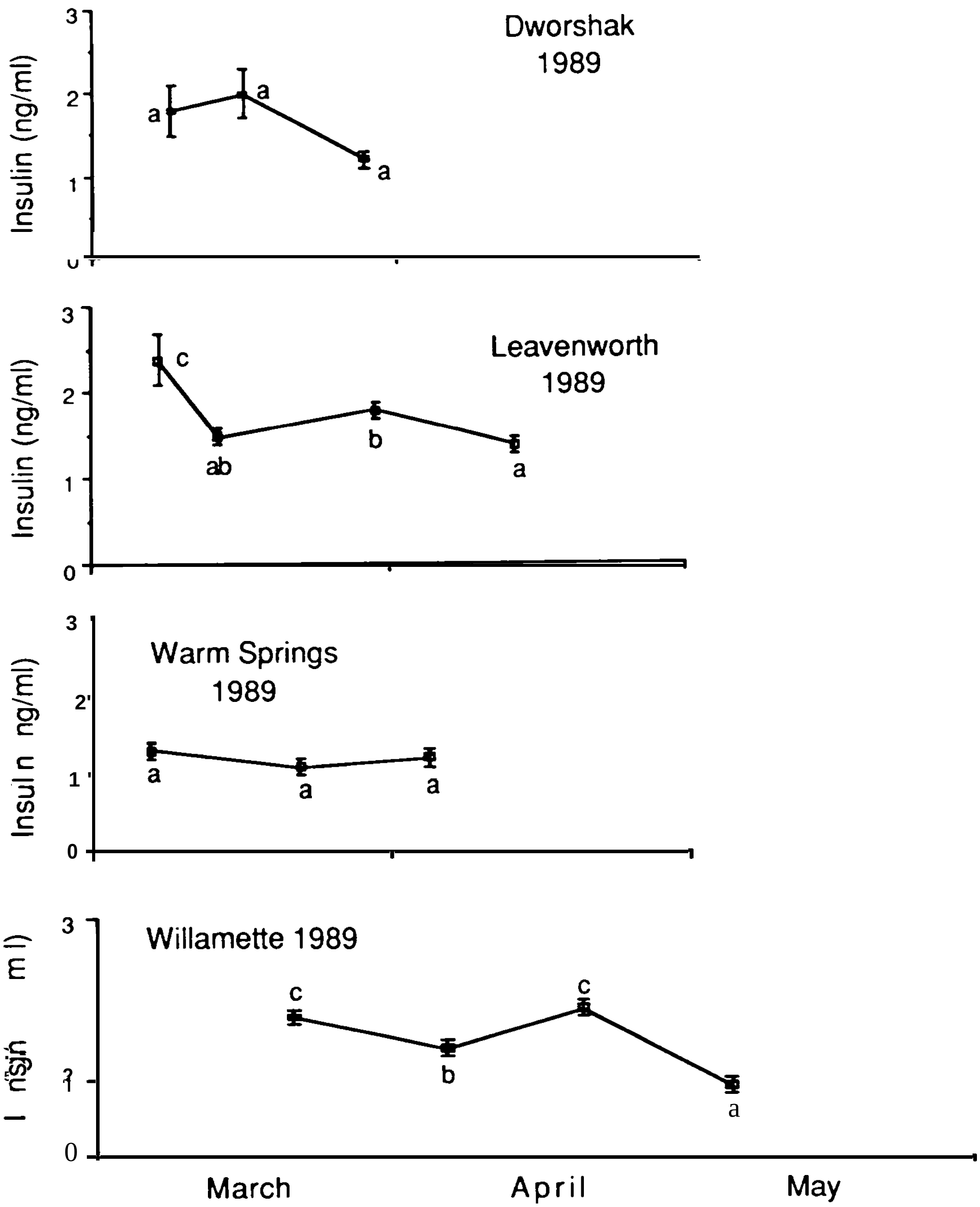


Figure 10.--Plasma concentrations of insulin in sampled fish at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Letters next to the symbols indicate significant differences within a hatchery ($P < 0.05$; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

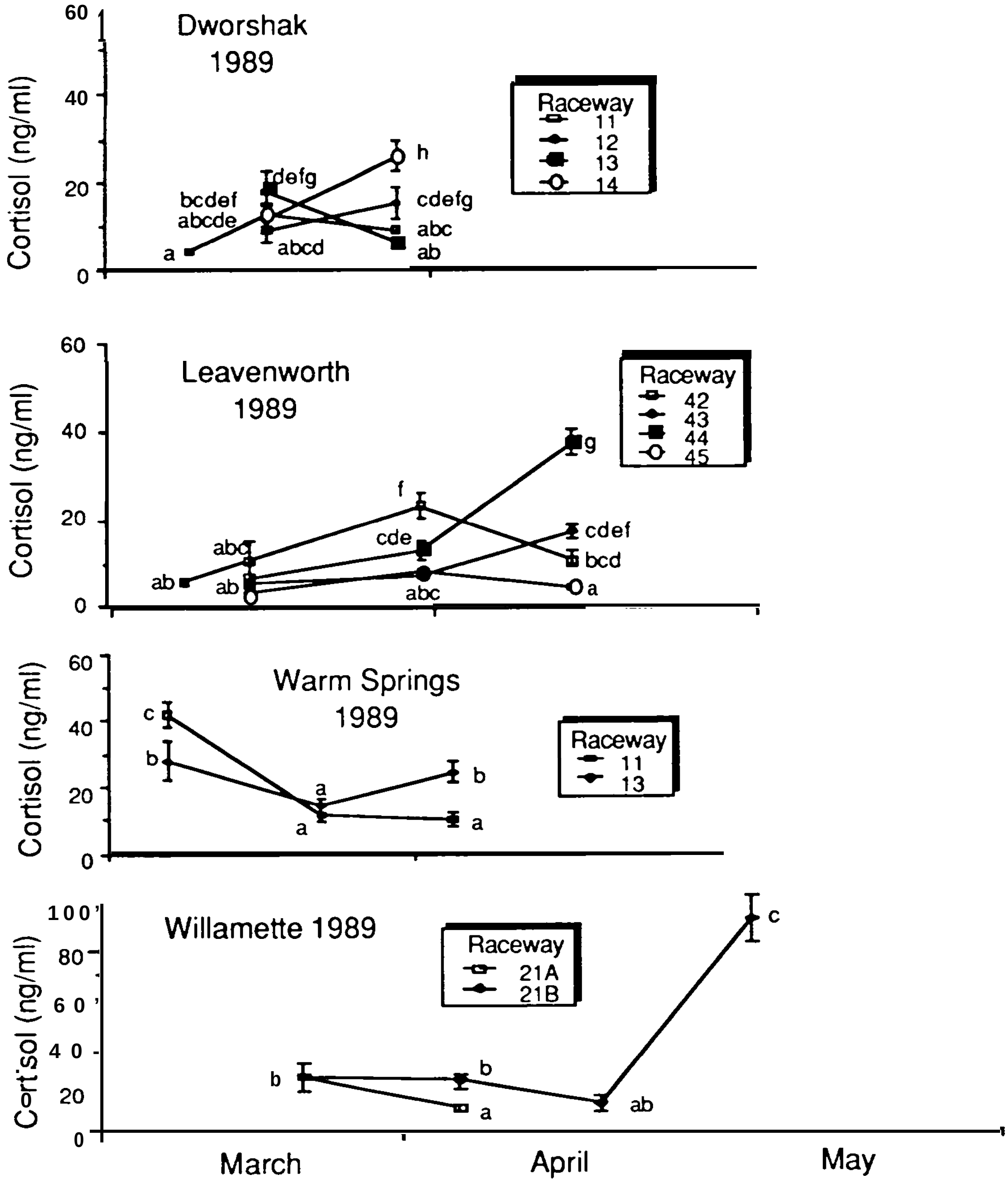


Figure 11.--Plasma concentrations of cortisol in sampled fish at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Letters next to the symbols indicate significant differences within a hatchery ($P < 0.05$; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

Warm Springs may not be resting levels of T4. The basis for this speculation is the observation that novel fresh water causes a transient elevation in blood levels of T4 in salmon during smoltification (Dickhoff et al. 1982a; Nishioka et al. 1985). Presumably the novel freshwater response in T4 is olfactory-mediated, and may be involved in homing imprinting. At Willamette Hatchery, T4 levels were highest in the late April and early May samples for raceway 21 B (Fig. 8). In general, T4 levels increased during the sampling period in Dworshak and Willamette fish, and decreased in Leavenworth and Warm Springs fish. The clearest indication of an expected increase in T4 was observed in the Willamette fish in raceway 21B.

At Dworshak Hatchery, mean plasma T3 levels decreased during March in fish in raceways 13, increased in fish in raceway 12, and showed no significant change in fish in raceway I4 (Fig. 9). At Leavenworth Hatchery, T3 levels increased in fish in all raceways, and there were consistent differences among the raceways sampled. Consistently higher mean T3 levels were observed in fish from raceways 43,45 and 44, progressively. Mean T3 levels in the fish at Warm Springs (raceway 13) were constant between mean values of 6.7 and 8.9 ng/ml. The data on T3 levels in fish at Willamette Hatchery are available only for raceway 11 on 4 April due to a problem with processing the samples in the laboratory. However, the mean was 10.1 with a standard error of 0.6; this was the highest value for T3 of all groups sampled.

Plasma insulin concentrations are shown in Figure IO. At Dworshak Hatchery (raceway 1 l), mean plasma insulin levels showed no significant change, and remained within the 1 to 2 ng/ml range. At Leavenworth Hatchery (raceway 42), mean plasma insulin declined from an initial high of 2.3 ng/ml to I .4 ng/ml during March and then remained relatively constant in subsequent samples. There was no significant change in plasma insulin in fish at Warm Springs Hatchery (raceway 1 I) throughout the sampling period. Plasma insulin was relatively high in the first three sampling periods in fish at Willamette (raceway 21 B), and then it declined to a low of 0.8 ng/ml in fish near the time of release. In coho salmon, insulin levels decline from levels ranging from 1.5 to 7 ng/ml in parr to levels in the range of 0.7 to 1 ng/ml just prior to smoltification (Plisetskaya et al. 1988). These data suggest that smoltification is beginning in the fish at Willamette and Leavenworth Hatcheries, but not at Dworshak and Warm Springs Hatcheries. Alternatively, the lack of change in insulin levels in fish at Dworshak and Warm Springs may be due to infrequent sampling. The lowest mean insulin levels were observed in fish near the time of release from Willamette Hatchery, suggesting that these fish were the most advanced in smolting.

Resting (presumably non-stress) levels of plasma cortisol are shown in Figure 11. At Dworshak Hatchery, there was an increase in mean plasma cortisol in fish sampled after the initial sampling. By the last sampling date at Dworshak, plasma conisol was significantly elevated over initial levels only in sampled fish in raceways 12 and 14. At Leavenworth Hatchery, mean plasma cortisol showed significant increases during the sampling period in fish in raceways 42,43 and 44; there was no significant change in plasma cortisol in fish in raceway 45. Highest mean plasma cortisol was observed at the time of release of fish in raceways 43 and 44. At Warm Springs Hatchery, the mean levels of cortisol were initially elevated (20 to 50 ng/ml); they declined in the subsequent sampling periods. At the time of release, mean plasma cortisol was higher in fish in raceway 13 compared to raceway 11. It was noted at the time of the first sampling at Warm Springs that the hatchery water was unusually silted. A large amount of silt had just appeared in the water at the time the sampling crew arrived at the hatchery. At high levels of silting, conisol levels may be elevated (Redding et al. 1987). If the fish sensed this siltation as a stressor, then the relatively high cortisol IeveIs measured in the first sampling point at Warm Springs may not be resting levels of cortisol. At Willamette Hatchery, mean plasma cortisol showed a declining tendency from March to April; there was a marked elevation in cortisol at the time of release of fish in May. At the time of the last sampling of fish at Willamette, the pond containing the fish had been drained to one-half capacity in preparation for release of the fish. The sampling crew observed the fish in the low water conditions, and concluded that the fish were agitated. The relatively high levels of cortisol in the May samples at Willamette are comparable to cortisol levels in acutely stressed fish, and probably reflect stress levels and not resting levels. In general, elevated levels of cortisol were observed in fish at all hatcheries. There was little consistency comparing cortisol levels in fish in different raceways within a hatchery on the same sampling date, but this may have been due to occasional activity of hatchery personnel in adjacent raceways. Since significant elevation in plasma cortisol is often observed in salmonids during smoltification, these results suggested that only the fish in the May release group at Willamette and some fish at Leavenworth and Dworshak showed typical indications of smolting (Patiño et al. 1986). However, in view of the probability that the fish in the May sample at Willamette were stressed, no clear conclusions can be made regarding the degree of smolting based on resting cortisol levels of the various groups.

Secondary Stress

Fish were subjected to a secondary stress test comprised of I hour of confinement in a bucket suspended in the raceway. Blood plasma cortisol was measured as an indicator of the stress response. Plasma cortisol concentrations after stress are shown in Figure 12. At both Dworshak and Leavenworth Hatcheries, mean plasma cortisol levels were usually in the range of 60 to 120 ng/ml throughout the sampling period, and there was no consistent trend toward increasing or decreasing cortisol values. At both Warm Springs and Willamette Hatcheries, stress levels of cortisol showed an increasing trend over time. An increase in stress-induced cortisol levels as smoltification progresses is anticipated based on work that demonstrated an increasing sensitivity of cortisol production by the interrenal tissue in response to adrenocorticotropic hormone (ACTH; Young 1986). It is interesting to note that at Warm Springs Hatchery, fish at low density (raceway 11) had significantly lower stress levels of cortisol during the earliest stress treatment. Differences between stress-induced cortisol levels disappeared in subsequent tests of fish at Warm Springs. At the time of release of Warm Springs fish, and for the May release group at Willamette, mean cortisol levels after stress went above 150 ng/ml.

Blood glucose levels in fish subjected to stress are shown in Figure 13. Overall, blood glucose values ranged from 81 to 190 mg/dL. The ranges in plasma glucose (mg/dL) for each hatchery were: Dworshak, 81 to 190; Leavenworth, 88 to 176; Warm Springs, 87 to 125; Willamette, 96 to 140. These ranges in plasma glucose in stressed fish are 30 to 45 mg/dL higher than the ranges in plasma glucose for unstressed fish (compare with Fig. 14). There was no consistent trend toward increasing or decreasing blood glucose in the data at any hatchery during the sampling period. In general, the highest plasma glucose levels in response to stress were observed in fish at Leavenworth Hatchery.

Metabolic Indicators

Increased metabolic rate during smolting is associated with declines in metabolic stores of glycogen and lipid (Hoar 1988). Blood plasma glucose levels would not be expected to change if the fish are not stressed and are maintained on an adequate dietary ration. The metabolic state of the fish was evaluated by measuring blood glucose and liver glycogen and triglyceride concentrations. For this evaluation, fish were sampled shortly before release from the hatcheries (also 1 month before release at Leavenworth and Willamette Hatcheries).

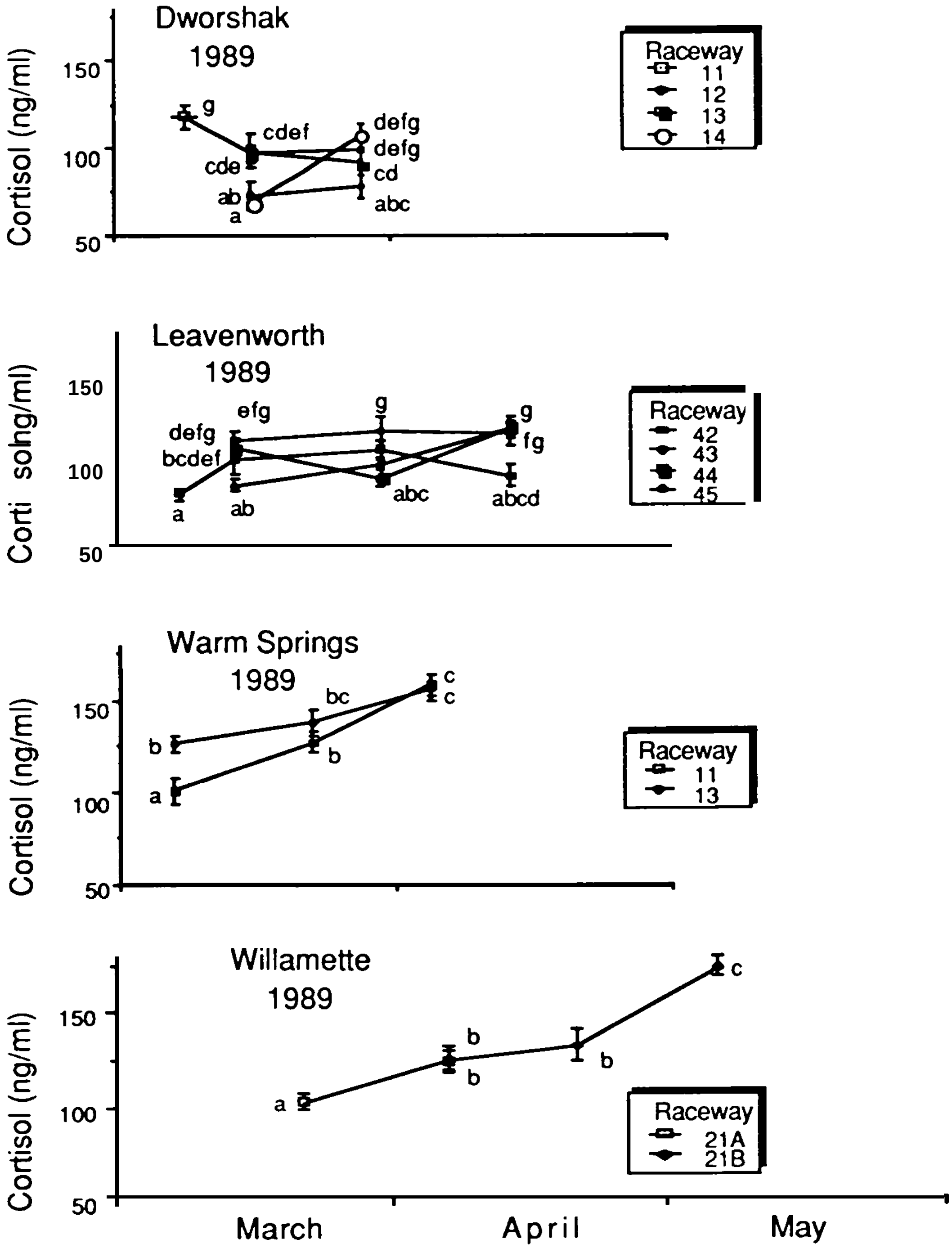


Figure 12.--Plasma concentrations of cortisol in fish subjected to confinement stress at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Letters next to the symbols indicate significant differences within a hatchery ($P < 0.05$; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

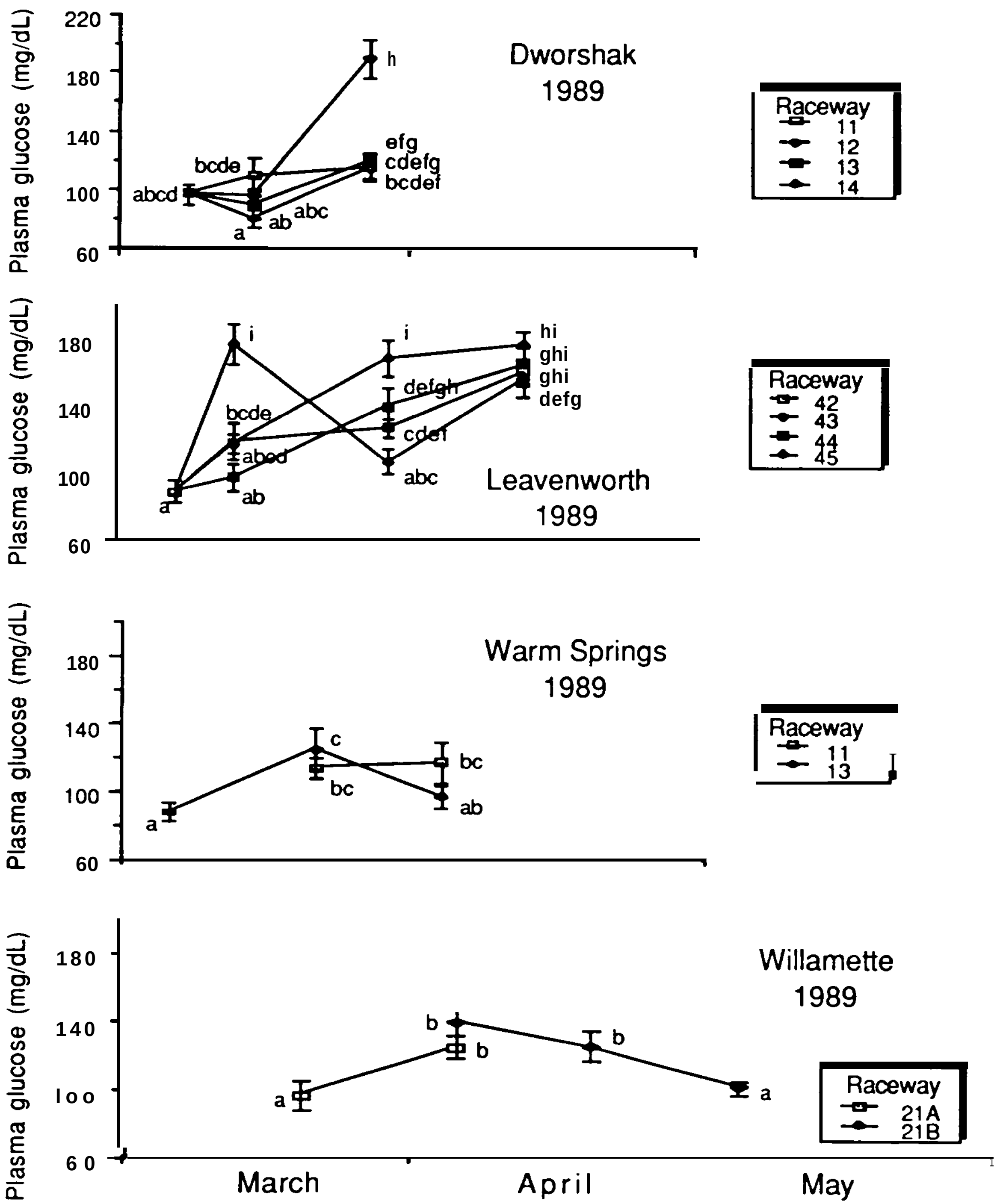


Figure 13.--Plasma concentrations of glucose in fish subjected to confinement suess at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Letters next to the symbols indicate significant differences within a hatchery ($P < 0.05$; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

Plasma glucose -- Plasma concentrations of glucose in fish that were not subjected to stress are shown in Figure 14. Plasma glucose ranged from 50 to 160 mg/dl. For fish from individual hatcheries, the ranges in plasma glucose (mg/dl) were: Dworshak, 61 to 145; Leavenworth, 52 to 144; Warm Springs, 50 to 132; Willamette, 73 to 133. In general, there was no consistent uend toward increasing or decreasing concentrations of plasma glucose over time. The observed ranges in plasma glucose are approximately 30 to 45 mg/dl below those observed in fish subjected to confinement stress (Fig. 13). Furthermore, it is interesting to note that at Warm Springs Hatchery, plasma glucose concentrations were lower in fish held at low density compared to those held at normal density. These results suggested that fish sampled for evaluation of metabolic state were not exceptionally stressed.

Liver glycogen -- The expected pattern of change in liver glycogen during smolting is a decrease over time from relatively high levels accumulated in parr prior to smolting. The highest mean glycogen concentrations were found in the fish sampled in March at Leavenworth and Dworshak Hatcheries (Fig. 15). There was a slight decline in mean liver glycogen in fish at Leavenworth between March and April sampling dates, but this decline was statistically significant only for fish in raceway 43. Liver glycogen was relatively low in fish sampled at Warm Springs and Willamette Hatcheries during March. Considering the sampling dates closest to the time of release only, the lowest mean glycogen was found in Willarnette fish in raceway 21B; the next lowest glycogen was observed in Warm Springs fish. These data suggested that the May release fish at Willamette Hatchery were the most advanced in smolting at the time of release.

Liver triglyceride -- The expected pattern of change in liver triglyceride concentration during smolting is a decrease from relatively high levels accumulated in parr prior to smolting. In general, for the fish sampled, there was a trend of decreasing liver triglyceride over time (Fig. 16). The highest mean concenuation of triglyceride was found in the groups of fish sampled at the Leavenworth Hatchery on 13 March. At Leavenworth, there was a significant decline in triglyceride comparing the March and April values. Concenuations of triglyceride in the fish sampled at Dworshak Hatchery in March, and at Willamette Hatchery in May, were less than half those observed in the fish at Leavenworth in March. The lowest mean liver triglyceride was observed in Willamette fish in raceway 21B on 4 May. Considering the sampling dates closest to the time of release only, low liver triglyceride concentrations were found in Willamette (May release) and

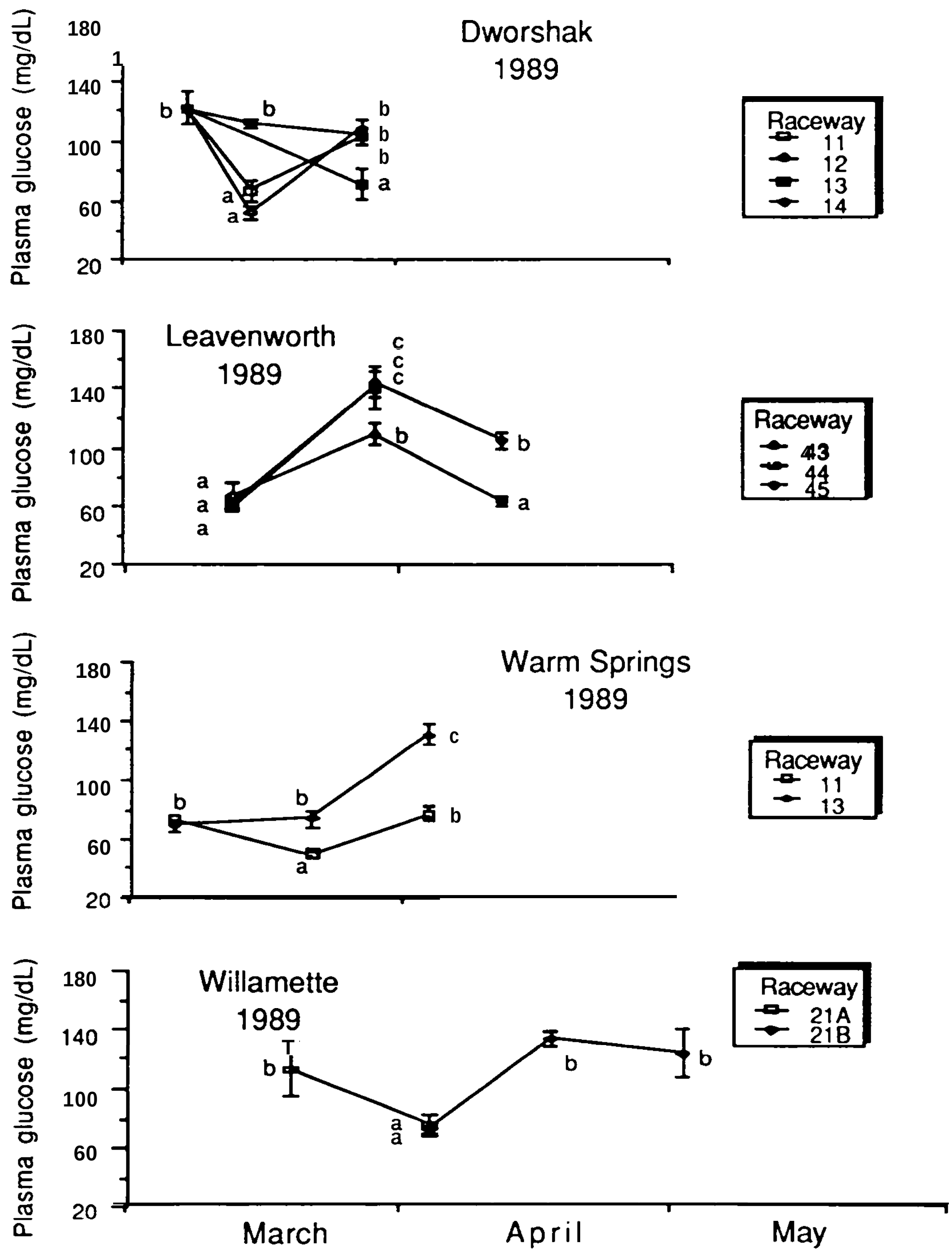


Figure 14.--Plasma concentrations of glucose in unstressed fish at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Letters next to the symbols indicate significant differences within a hatchery ($P < 0.05$; ANOVA, Fisher PLSD). Points with a common letter are not significantly different.

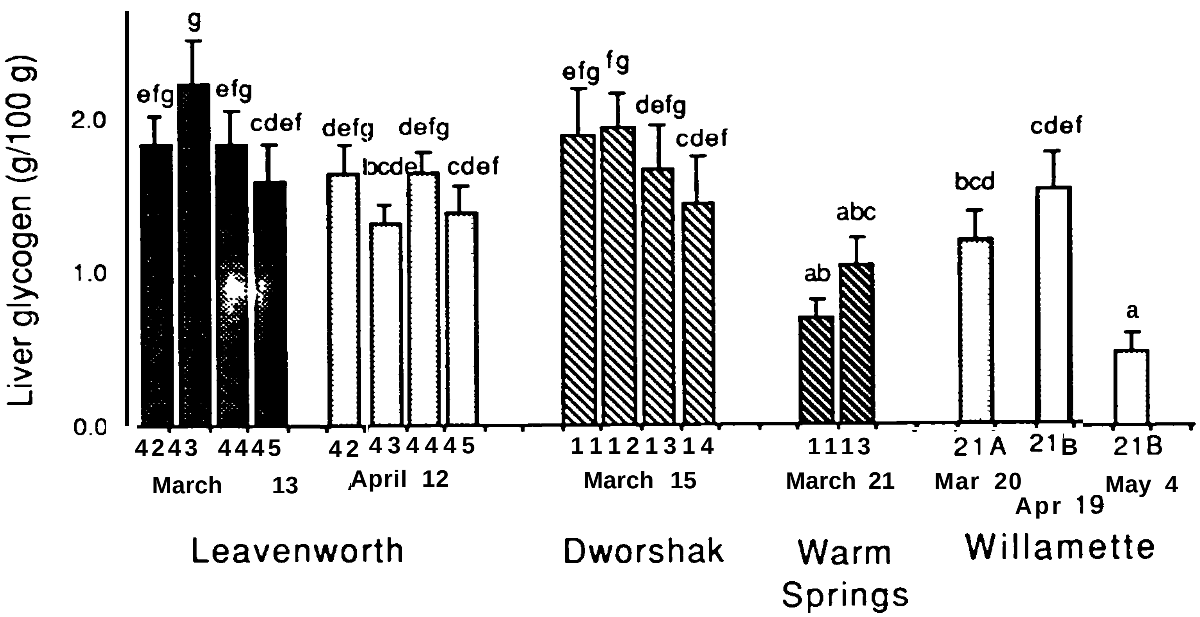


Figure 15.--Liver glycogen content (g/100 g) of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences ($P < 0.05$; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

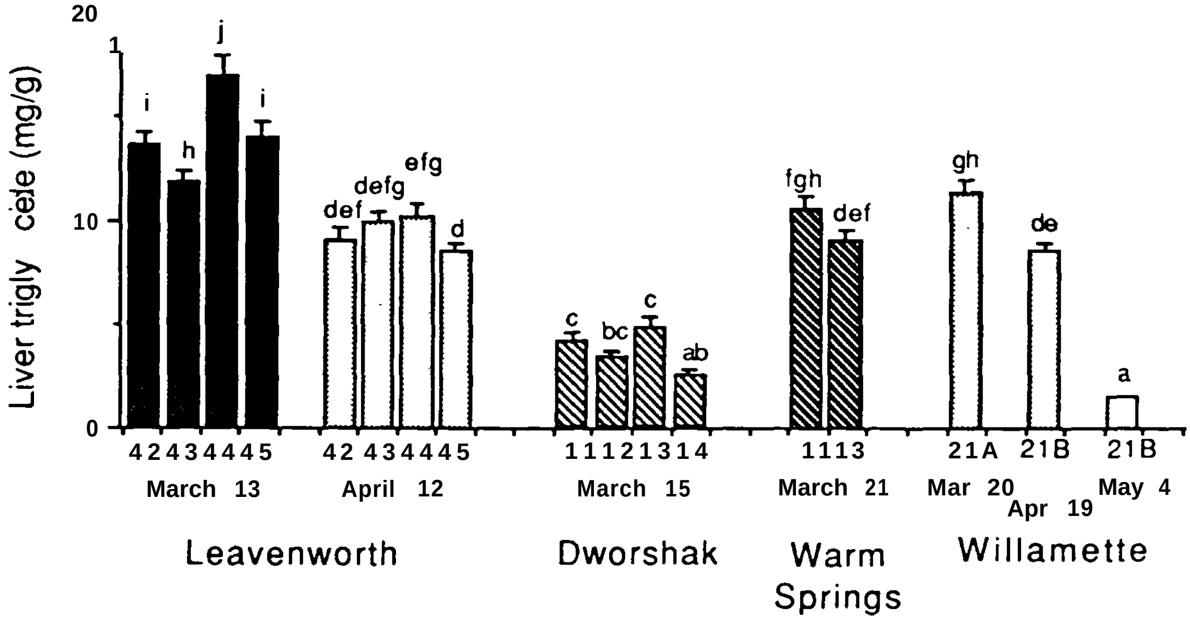


Figure 16.-- Liver triglyceride content (µg/mg) of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences ($P < 0.05$; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

Dworshak fish. At the time of release, triglyceride levels were approximately equivalent in fish at Leavenworth, Warm Springs, and Willamette (April release) Hatcheries.

Morphological Indicators

Characteristic morphological changes in fish during smoltification include streamlining of body shape and increase in silver color of the skin (silvering is due to guanine deposition). These parameters were evaluated using morphometric analysis and skin guanine concentration determined shortly before release from the hatcheries (also 1 month before release at Leavenworth and Willamette Hatcheries).

Morphometrics - -The change in body shape of the fish sampled was analyzed by determining PC values (Winans 1984). The criterion for smolts according to PC analysis is a reduction of the value to less than zero. The results are shown in Figure 17. At Dworshak Hatchery there was a decreasing trend in mean PC measurements in all groups. The values went from an initial point of 1 to 0 in two groups, and from 1 to -1 for the fish in raceway 14. At Dworshak, only the group in raceway 14 had PC values significantly below zero. However, approximately half of the fish in raceway 14 had been freeze-branded, a stressful procedure that may have affected their health. In support of this notion, these fish had elevated cortisol (Fig. 11). At Leavenworth Hatchery the mean PC values varied between 0.5 and -1 in all groups, and there was no consistent increasing or decreasing trend. At Leavenworth, fish in raceways 42 and 43 had PC values significantly below zero on 13 March. At Warm Springs, the mean PC values varied between 0.5 and -0.5, and there was no marked trend. The only PC value significantly below zero was for fish in raceway 11 on 21 March. At Willamette Hatchery, mean PC values increased from initial values and then declined. There was no point at which the PC values were significantly below zero for fish at Willamette.

Skin guanine - - Mean skin guanine content was highest in fish sampled at Willamette Hatchery in March and April, but it was the lowest of all groups sampled in raceway 21B on 4 May at Willamette Hatchery (Fig. 18). In Leavenworth fish, there was a trend of increasing skin guanine from the March to the April sampling dates, although the increase was significant only for fish in raceway 44. Considering only the March sampling dates for all hatcheries, the highest to the lowest mean skin guanine contents were observed in Willamette, Dworshak, Warm Springs, and Leavenworth, respectively. Since silvering of the skin is due to guanine deposition, a characteristic of smolting, it could be speculated

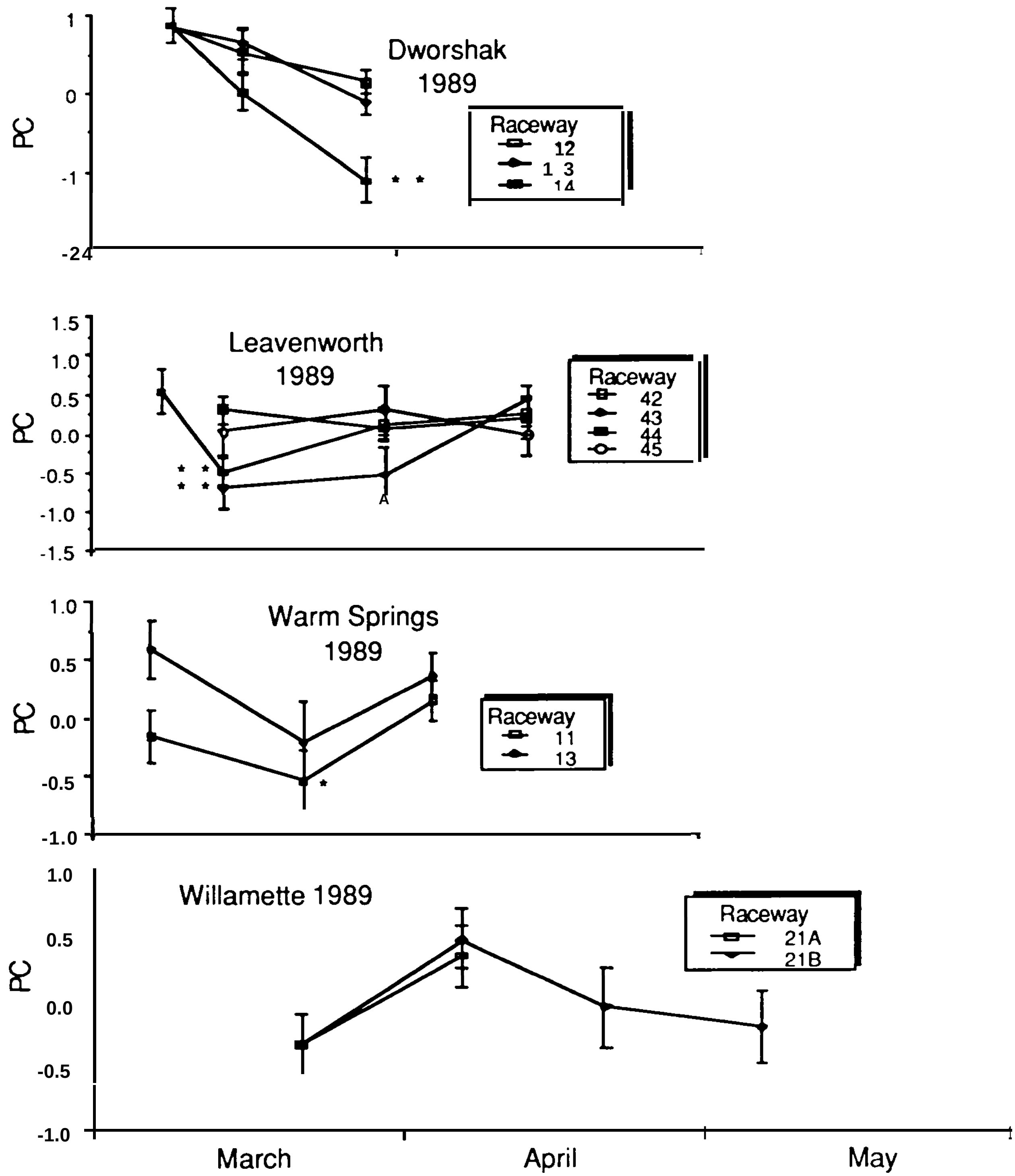


Figure 17.-- Morphometrics of body shape using principal component (PC) analysis at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Asterisks indicate values significantly less than zero (* = P < 0.05; ** = P < 0.0 1: t-test).

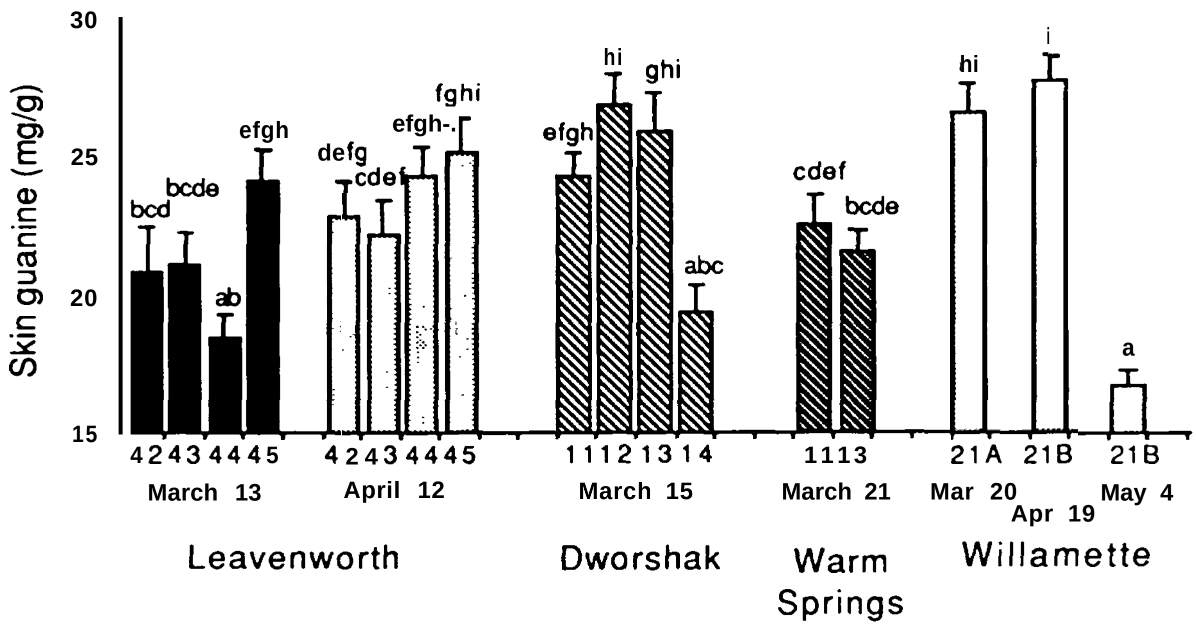


Figure 18.--Skin guanine concentrations in fish sampled at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences ($P < 0.05$; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

that Willamette fish showed the highest and Leavenworth fish showed the lowest degree of smolting. The decrease in mean skin guanine concentration from 19 April to 4 May in fish at Willamette Hatchery is an unexpected finding. The fish at Willamette Hatchery on 4 May had not shown any visible reduction in silvery appearance compared to the fish at earlier sampling dates. The relationship between skin guanine content, as measured, and the silvery appearance of the skin is not well-established. Differences in the amount of non-pigmented portions of the dermis, the amount of skin adhering to the muscle, loss of scales, or the amount of adhering muscle tissue in the skin samples, may interfere with accurate measurement of guanine concentration in the pigmented layers of the skin.

Salt and Water Balance in Fresh Water

Muscle water content -- The concentration of water in dorsal skeletal muscle tissue was determined shortly before release of fish from the hatcheries (also 1 month before release at Leavenworth and Willamette Hatcheries). The mean tissue water concentrations were similar at all dates for the fish at Leavenworth, Dworshak, and Warm Springs Hatcheries (Fig. 19). The lowest mean tissue water was observed in Willamette fish in raceway 2 1 A during March. Subsequent samples from fish in raceway 21B at Willamette Hatchery showed a significant increase in muscle water.

Plasma ion and protein concentrations -- The concentrations of blood plasma sodium, potassium, chloride, and total protein were determined shortly before release from the hatcheries (also 1 month before release at Leavenworth and Willarnette Hatcheries). These parameters are indicators of general physiological state with regard to salt- and water-balance of the fish. There were no striking differences in the plasma concentrations of ions or protein between hatcheries (Figs. 20 - 23), although there were some statistically different values between groups. All mean values for ion and protein concentrations were within the normal ranges for healthy fish (Wedemeyer and Yasutake 1977). For plasma sodium, the lowest values were in fish at Willamette Hatchery, particularly in May (Fig. 20). The highest plasma sodium was in fish in raceway 44 at Leavenworth Hatchery on 29 March. Plasma potassium levels were uniformly low in Leavenworth fish sampled in March (Fig. 21). For plasma chlorides, most of the highest values were in fish at Leavenworth (with the exception of raceway 45 on 12 April). Plasma protein levels tended to be lowest in fish at Leavenworth Hatchery, whereas consistently higher levels were observed in fish at Warm Springs and Willamette Hatcheries.

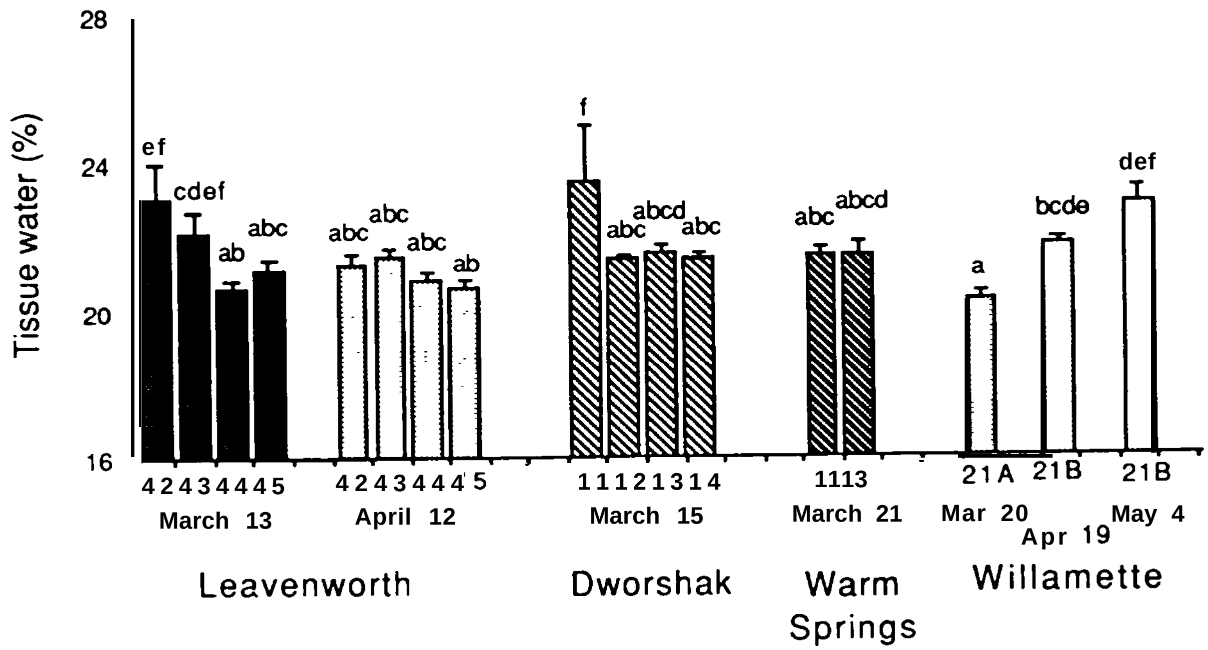


Figure 19.--Tissue water content (%) of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences ($P < 0.05$; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

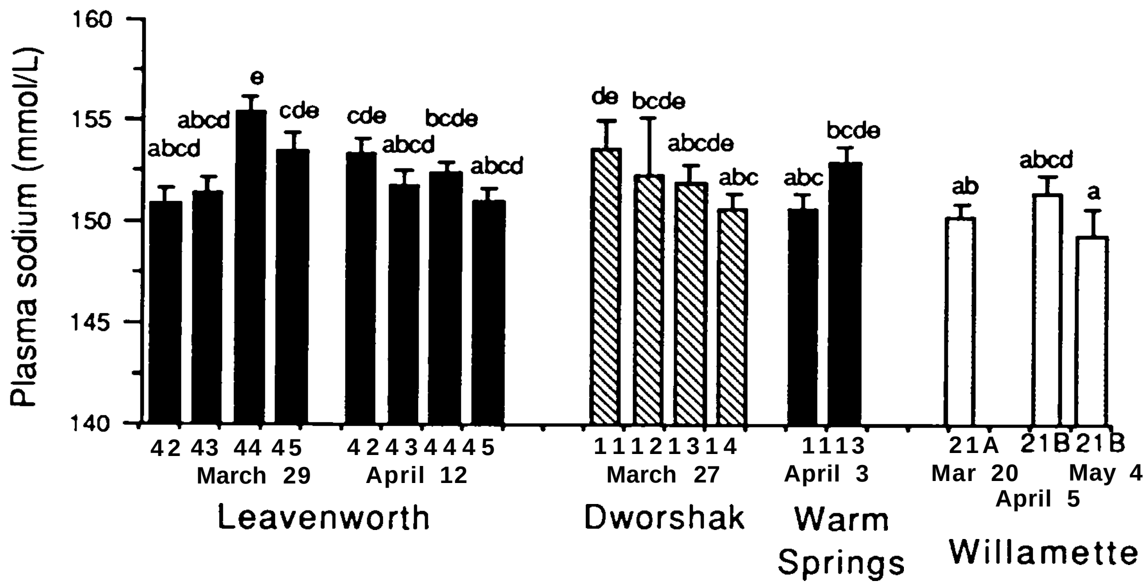


Figure 'O.--Plasma sodium concentration of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences ($P < 0.05$; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

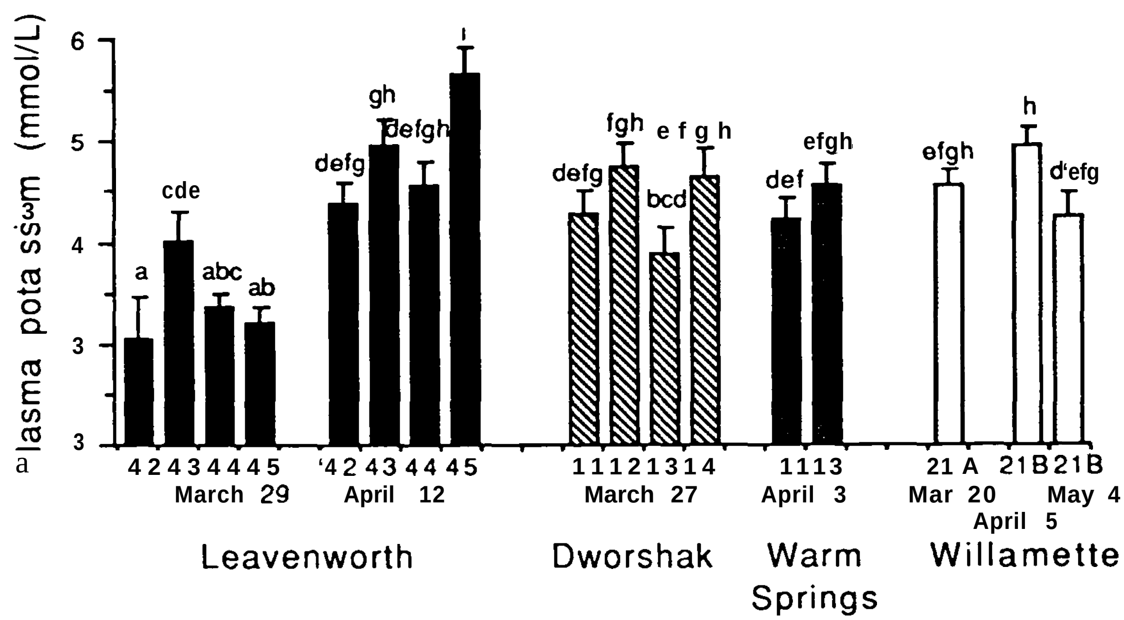


Figure 2 1 .--Plasma potassium concentration of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences (P c 0.05; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

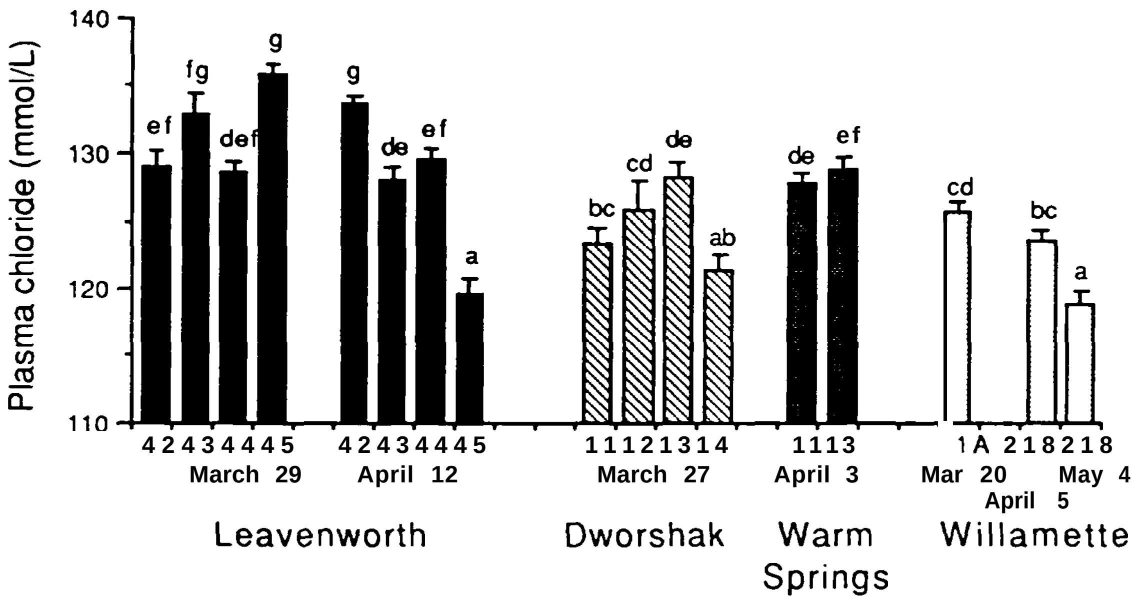


Figure 22.--Plasma chloride concentration of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences (P < 0.05; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

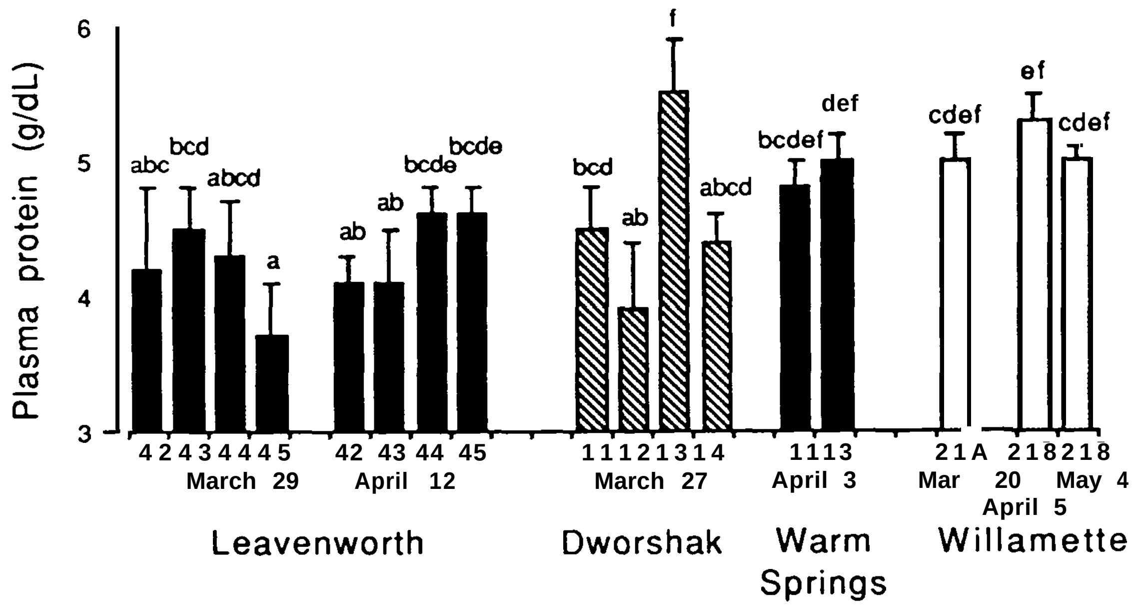


Figure 23.--Plasma protein concentration of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences (P < 0.05; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

Blood Cells

The total number and proportion of red blood cells, white blood cells, and white cell types are indicators of general health of fish. Hematocrits were determined every 2 weeks. The number of white cells and differential white cell counts were determined for fish sampled shortly before release, and also 1 month before release at Leavenworth and Willamette Hatcheries.

Hematocrit - - Hematocrit values for blood samples from fish at the various hatcheries ranged from 25 to 40% (Fig. 24). At all times in fish at all hatcheries, hematocrit values were within normal ranges for healthy fish (Wedemeyer and Yasutake 1977). At Dworshak Hatchery, hematocrits declined from initial values in fish in raceways 12 and 14, but remained relatively constant in raceways 11 and 13. For fish at Leavenworth, hematocrits declined from initial high values in three of the four raceways examined. At the end of sampling at Leavenworth, hematocrits had returned to near initial values in fish in raceways 43 and 45, but not in raceways 42 and 44. At Warm Springs, hematocrits were initially high in the fish held at normal density (raceway 13) compared to one-half normal density (raceway 11). For fish in both raceways at Warm Springs, hematocrits declined to significantly lower values in late March and early April samples. At Willamette, there was no significant change in hematocrit values over time for fish in raceway 21A. For fish in raceway 2 1 B, there was a significant increase in hematocrits from early April to shortly before release.

Statistical analysis of all hematocrit data showed that most of the fish at Dworshak Hatchery had significantly lower hematocrits compared to fish at the other three hatcheries. The reason for this difference is not clear. Low water temperature may increase hematocrits in salmonids (Dewilde and Houston 1967); however, the fish at Dworshak were at similar or higher temperature (5^o-6^o C) compared to those at Leavenworth Hatchery (2^o -6.50 C), for example. A relatively high incidence (up to 40%) of bacterial kidney disease had been diagnosed for Dworshak fish (Warren 1989). Kidney damage from this disease may have reduced hematocrit.

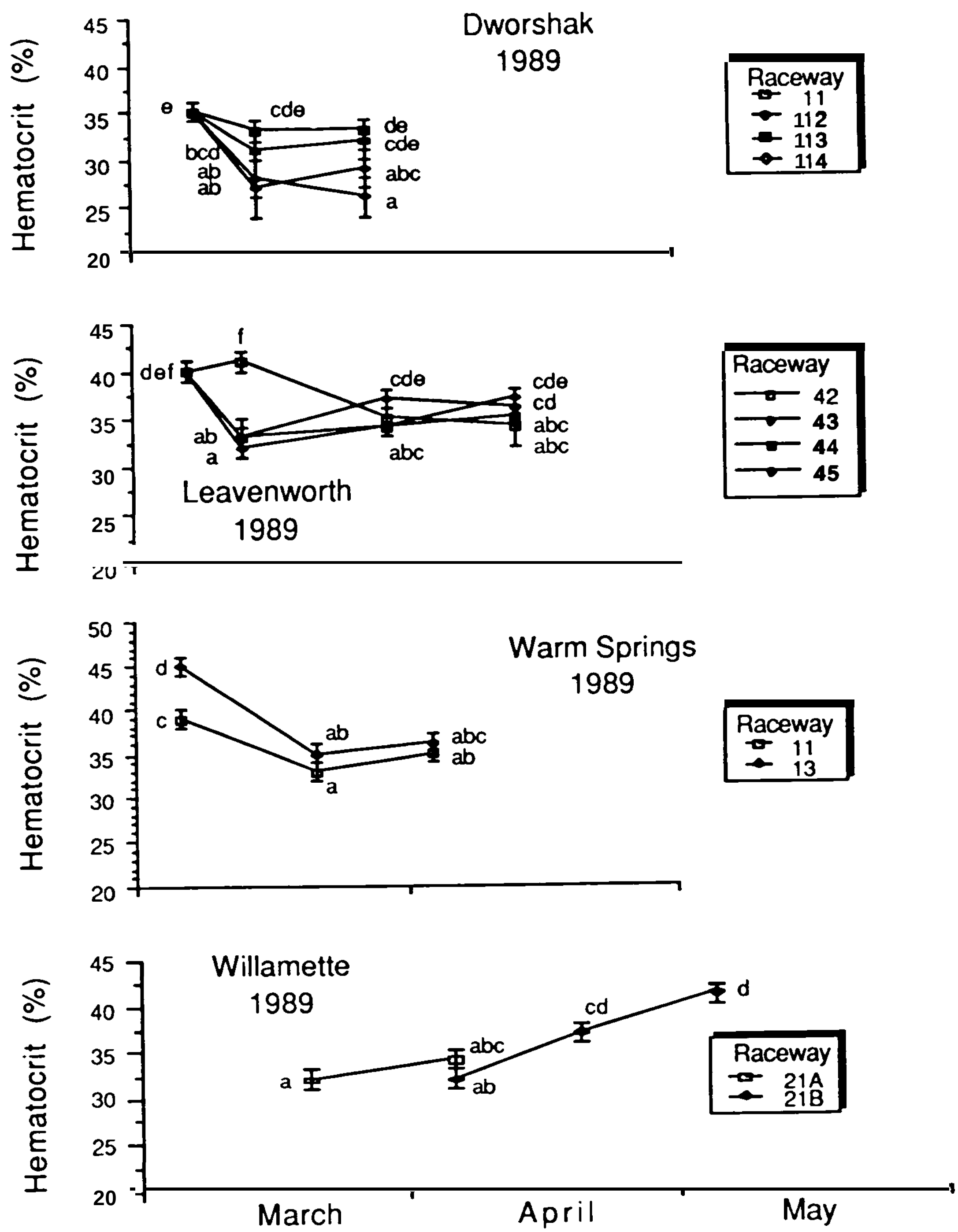


Figure 24.--Hematocrits of fish at the indicated hatcheries. Symbols indicate means; brackets indicate ± one standard error. Letters near symbols indicate significant differences within a hatchery (P < 0.05; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

White cell count - - The mean white cell counts of fish from all hatcheries were between 0.6 and 0.9% of total blood cells (Fig. 25), which is within the normal range observed for healthy juvenile salmon (Wedemeyer and Yasutake 1977). The only statistically significant differences in white cell counts among all groups of fish examined were in the fish at Dworshak Hatchery.

Lymphocytes - - The proportion of lymphocytes in fish at all hatcheries was between 87 and 97% of the total white cell count (Fig. 26). This range of lymphocyte percentage is close to the normal range (89 - 98%) reported for healthy rainbow trout (Wedemeyer and Yasutake 1977). The highest lymphocyte proportion was found in fish in raceway 21 B at Willamette Hatchery. The lowest proportion of lymphocytes was observed in fish in raceway 42 on 29 March at Leavenworth Hatchery.

Neutrophils - - The mean proportions of neutrophils in fish at all hatcheries were between 4 and 12% of total white blood cells (Fig. 27). The reported normal range for neuuophils in healthy juvenile rainbow trout is 1 to 9% (Wedemeyer and Yasutake 1977). The only groups outside the normal range were fish in raceway 42 at Leavenworth on 29 March and in raceway 14 at Dworshak on 27 March. The lowest neutrophil counts were for fish in raceway 21B at Willamette Hatchery.

Monocytes - - hlonocytes were observed only occasionally in blood samples from all fish, and the incidence of monocytes was not strikingly higher in any group.

Immune Competence

The capacity for immune response by cultured anterior kidney lymphocytes was examined for fish at Dworshak, Warm Springs, and Willamette Hatcheries (Table 2). Fish at Dworshak Hatchery showed no immune response on the date tested. The greatest immune response, as determined by the number of plaques formed, was from fish at Willamette Hatchery on 5 and 19 April. There was no correlation between either the number or types of white blood cells and the capacity for immune response.

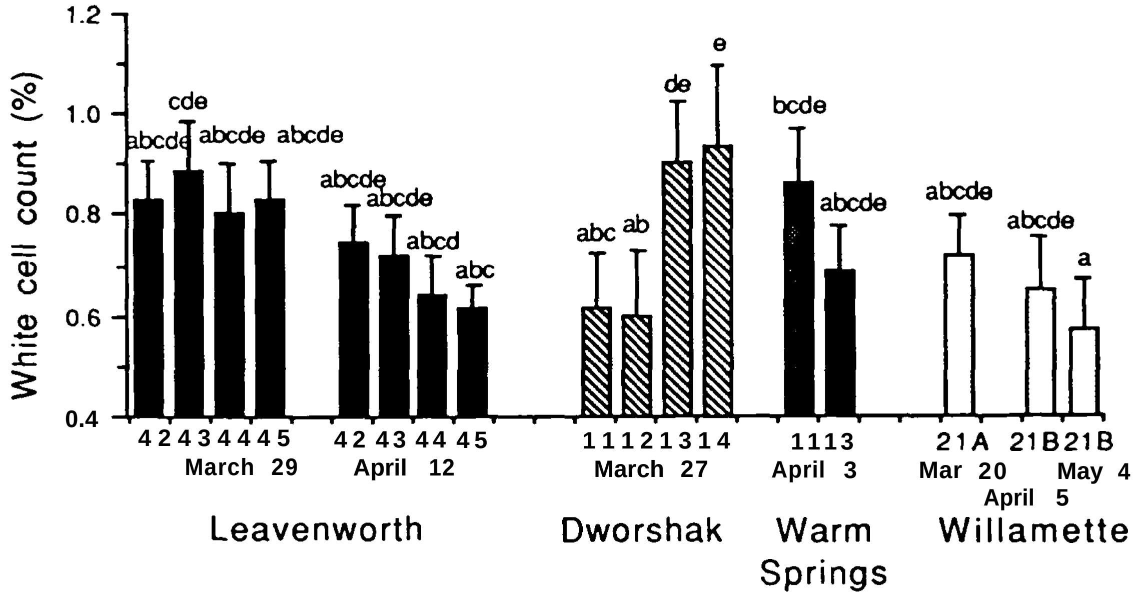


Figure 25.--White cell count (% of total blood cells) of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences (P < 0.05; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

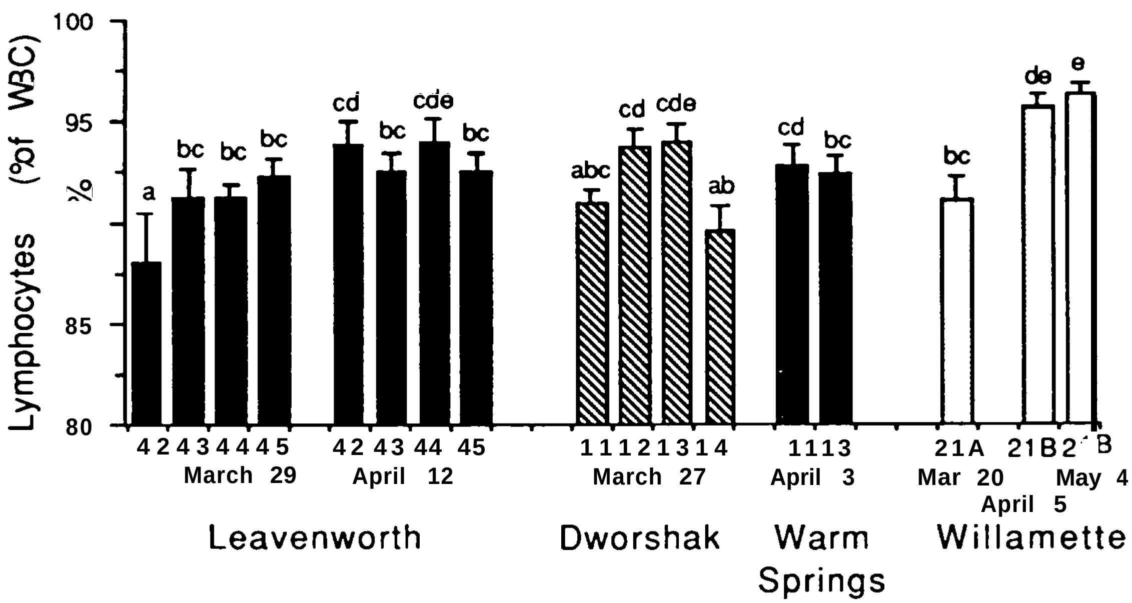


Figure 26.--Blood concentration of lymphocytes (% of white blood cells) of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences (P < 0.05; ANOVA, Fisher PLSD). Bars with a common letter are not significantly different.

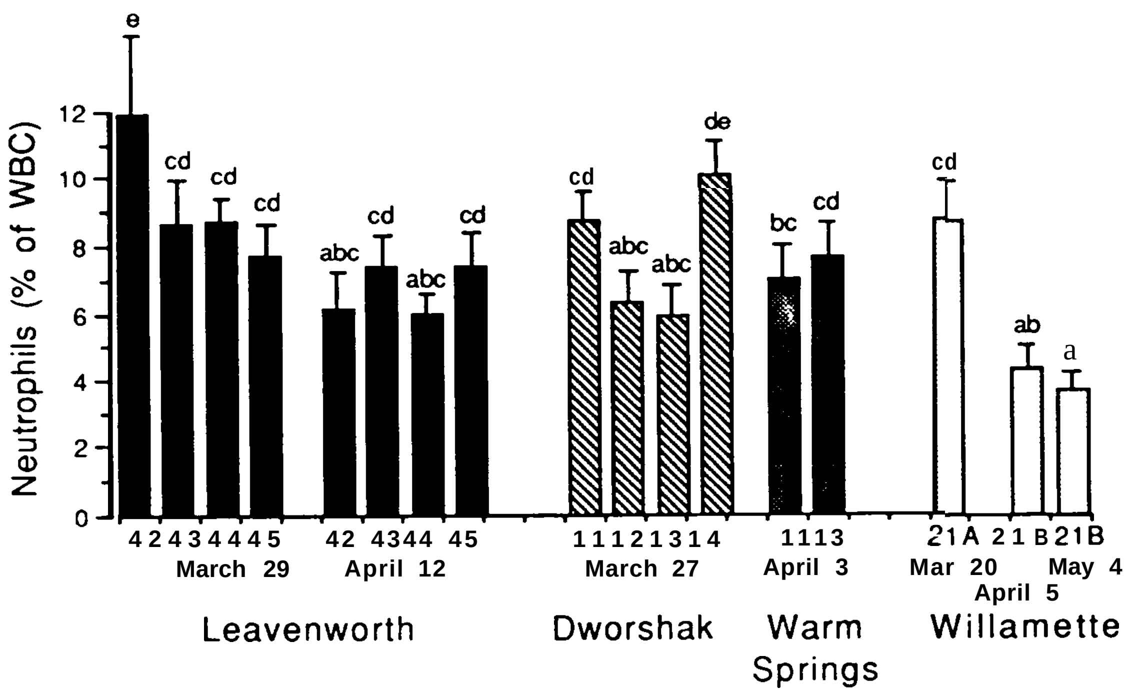


Figure 27.--Blood concentration of neutrophils (% of white blood cells) of fish at the indicated hatcheries. Vertical bars indicate means; brackets indicate + one standard error. The numbers below the bars indicate raceway number and date of sampling. Letters above bars indicate significant differences (P < 0.05; AKOVA, Fisher PLSD). Bars with a common letter are not significantly different.

Table 2.-- Immune response of cultured anterior kidney lymphocytes from fish at Dworshak, Warm Springs, and Willamette Hatcheries sampled on the indicated dates. Formation of a plaque is indication of an antibody-producing cell.

Hatchery	Date	Raceway	Plaques/culture*
Dworshak	March 28	13	0^{a}
Dworshak	March 28	14	0^{a}
Warm Springs	April 3	11	98 ± 33^{b}
Warm Springs	April 3	13	196 ± 85^{bc}
Willamette	April 5	21 A	270 ± 52^{c}
Willamette	April 5	21 B	188 ± 55^{bc}
Willamette	April 19	21 B	298 ± 56^{c}
Willamette	May 4	21 B	183 ± 39^{bc}

* The number indicates the mean of 20 cultures ± one standard error. The superscript letters indicate statistical differences (ANOVA, Fisher PLSD, $P < 0.05$). Numbers that share a common superscript letter are not significantly different.

Relationship Between Replicate Raceways

Replicate raceways of production fish (four raceways) were sampled at Dworshak and Leavenworth Hatcheries to evaluate the degree of raceway-to-raceway variation in the measured parameters. Due to the time required for sampling, the four raceways were sampled over 2 days. At Dworshak, one set of samples was taken on 15 and 16 March; a second set was taken on 27 and 28 March. At Leavenworth, one set of samples was taken on 13 and 14 March, one set on 29 and 30 March, and a third set on 12 and 13 April. Each set of data was analyzed for significant differences using ANOVA and Fisher PLSD test at $P < 0.05$. Neither body weight nor fork length of the fish sampled from the four raceways in each set was significantly different, indicating that there was no size-dependent bias in any set of samples (Tables 3 and 4). Of the 25 parameters evaluated, body weight, body length, saltwater Na and K, gill ATPase activity of fish in fresh water, PC values, and white cell count showed no variation among raceways. Of the 379 measurements, there were 63 significant differences. Over half (37) of the observed differences were in plasma concentrations of T4, T3, cortisol, potassium, glucose, liver glycogen, and liver triglycerides, all of which have been shown to either vary diurnally, or change in relation to time after feeding (Eales et al. 1981; Laidley and Leatherland 1988). Thus, differences in time of day or in time after feeding when samples were taken may account for the observed variation. For example, comparison of T4 levels in fish sampled either in the morning or in the afternoon show little variation between raceways (Fig. 8). Therefore, for parameters that show circadian rhythm or a relationship to feeding, the time of day and time since last feeding should be standardized in the sampling procedure. For the remaining parameters, there were 26 differences out of 163 measurements. The 26 differences appeared to be randomly distributed among the parameters measured. Random differences may be due to the fact that measures of health may show wide variation because of major differences in disease in different raceways.

In general the differences observed were minor, usually within 10 to 20% of the average value for all groups. These differences were small in comparison to the seasonal changes anticipated for some of the parameters. For example, the differences in plasma T4 levels between replicate raceways was 2 to 4 ng/ml. The anticipated increase in plasma T4 associated with the parr-smolt transformation is at least a 10 to 20 ng/ml increase over the baseline value (Dickhoff et al. 1978, 1982b). Thus, the T4 elevation during smolting is much greater than either our observed variation between raceways or the circadian

Table 3.--Variation in measurements of fish from replicate raceways at Leavenworth Hatchery. Each set of four raceways was tested for significant differences ($P < 0.05$, ANOVA, Fisher PLSD). Dashes indicate no significant differences among raceways. Significant differences are indicated by letters. Raceways with common letters are not significantly different within the set of four raceways.

Date	March 13 - 14 Raceway				March 29 - 30 Raceway				April 12 - 13 Raceway			
Parameter	42	43	44	45	42	43	44	45	42	43	44	45
Weight	-	-	-	-	-	-	-	-	-	-	-	-
Length	-	-	-	-	-	-	-	-	-	-	-	-
Saltwater Na					-	-	-	-	-	-	-	-
Saltwater K					-	-	-	-	-	-	-	-
SW ATPase					a	a	a	b	-	-	-	-
FW ATPase					-	-	-	-	-	-	-	-
T4	ab	a	b	b	a	ab	b	b	a	a	b	b
T3		a	a	b		a	a	b		a	b	b
Cortisol	-	-		-	a	b	b	b	a	a	b	c
Stress Cortisol	a	a	a	b	a	b	a	a	a	b	b	b
Stress Glucose	a	a	a	b	ab	c	b	a	a	ab	b	ab
Normal Glucose		-	-	-		a	a	b		a	a	b
Liver Glycogen	ab	b	ab	a					-	-	-	-
Liver Triglyc.	b	a	b	c					ab	ab	b	a
Morphometric PC	-	-	-	-	-	-	-	-	-	-	-	-
Skin Guanine	ab	ab	a	b					-	-	-	-
Muscle Water	a	ab	c	bc					-	-	-	-
Plasma Sodium	a	a	b	ab					-	-	-	-
Plasma Potassium	a	b	ab	a					a	a	a	b
Plasma Chloride	a	a	a	b					a	b	b	c
Plasma Protein	ab	b	ab	a					-	-	-	-
Hematocrit	a	b	b	b	-	-	-	-	-	-	-	-
White Cell Count	-	-	-	-	-	-	-	-	-	-	-	-
Lymphocytes	a	b	b	b					-	-	-	-
Neutrophiis	a	b	b	b					-	-	-	-

Table 4.--Variation in measurements of fish from replicate raceways at Dworshak Hatchery. Each set of four raceways was tested for significant differences (P < 0.05, ANOVA, Fisher PLSD). Dashes indicate no significant differences among raceways. Significant differences are indicated by letters. Raceways with common letters are not significantly different within the set of four raceways.

Date	March 15 - 16 Raceway				March 27 - 28 Raceway			
Parameter	11	12	13	14	11	12	13	14
Weight	-		-		-	-	-	-
Length	-	-	-	-	-		-	-
Saltwater Na					-	-	-	-
Saltwater K					a	a	a	b
SW ATPase					b	a	b	ab
FW ATPase					-		-	
T4	a	a	b	a	-	-	-	-
T3		a	b	a		a	b	b
Cortisol	-	-	-	-	a	b	ab	c
Stress Cortisol	a	b	a	b	a	a	a	b
Stress Glucose	a	ab	ab	b	a	b	a	a
Normal Glucose	a	a	b	b	a	a	b	a
Liver Glycogen					-		-	-
Liver Triglyc.					b	ab	b	a
Morphometric PC	-	-	-	-		a	a	b
Skin Guanine					a	a	a	b
Muscle Water					a	b	b	b
Plasma Sodium					a	ab	ab	b
Plasma Potassium					ab	b	b	ab
Plasma Chloride					ab	bc	c	a
Plasma Protein					a	a	b	a
Hematocrit	ab	a	b	a	bc	a	c	ab
White Cell Count					a	a	b	b
Lymphocytes					ab	b	b	a
Neutrophils					ab	a	a	b

variation. Some of the observed differences may be partly due to lack of precision in measurement, or our inability to obtain a random sample of the population of production fish. Furthermore, we suspect that all raceways within a hatchery are not equivalent. Some of the differences may be spurious due to the large number of measurements analyzed at a significance level of $P < 0.05$. Regardless of its basis, variation will be accounted for in the final analysis of the reliability of measured parameters as indices for smolt quality. It is interesting to note that gill ATPase of fish in fresh water, and also saltwater challenge sodium levels, showed no significant variation; both of these measures are well-established indicators of smolt quality based on laboratory studies (Hoar 1988).

We concluded from the analysis of replicate raceways that the magnitude of raceway-to-raceway variation is not large enough to warrant multiple raceway sampling. Future sampling will rely on a single raceway per treatment group per hatchery.

Warm Springs Density Study

At Warm Springs Hatchery, raceway 11 had half the normal density of production fish, whereas raceway 13 was loaded at the normal density. Comparison of these two groups revealed differences in a few of the parameters measured. The size of the fish sampled was equivalent. At the last sampling date (3 April), the fish from raceway 11 were 139 ± 4 mm long (average ± standard error) and weighed 30.7 ± 2.6 g. On 3 April, fish sampled from raceway 13 were 141 ± 4 mm long and weighed 31.3 ± 2.3 g. The unstressed plasma cortisol level was significantly higher in fish from raceway 11 compared to 13 in early March (Fig. 1 1), but in April, plasma cortisol was higher in fish from raceway 13. Stress-induced cortisol elevation was significantly higher in fish in raceway 13 in early March, but not in subsequent tests (Fig. 12). The unstressed levels of plasma glucose were higher in fish in raceway 13 during the late March and April sampling dates (Fig. 14). The only other statistically significant difference observed between fish in raceways 11 and 13 was the higher hematocrits in fish from raceway 13 in early March (Fig. 24). These data suggest that fish at lower density have slightly different interrenal responses to handling stress, and their seasonal cortisol production or clearance may differ. There were no differences in performance in the saltwater challenge, thyroid hormone, or insulin profiles, liver glycogen or triglyceride, morphometrics, skin guanine, muscle water, plasma ions, white blood cell counts, or immune response. In general, there is little evidence to suggest that smolt quality differed substantially in the fish at these two densities.

SUMMARY

Although the main objective of this study is to evaluate smolt quality indicators based on adult survival, we can evaluate the degree to which the production fish at the four hatcheries conform to the expected pattern of smolting from previous studies. The expected changes are based primarily on laboratory studies of the relationship between the index measured and successful smolt performance (3- to 6- month survival and growth in seawater). Comparisons indicate that fish from Willamette Hatchery, particularly the May release group (raceway 21B), showed characteristic smolt development by the time of release (Table 5). Groups at the other hatcheries showed little or no development of smolt characteristics up to the time of release. We speculate that if the fish at Dworshak, Leavenworth, and Warm Springs Hatcheries had been held for a longer period before release, the parameters that we measured would have indicated significant development.

It might be predicted from these results that survival of adults from the production groups would be highest for the May release at Willamette. Fish released from the other hatcheries would have uniformly poorer survival compared to Willamette. The reliability of this prediction must wait until data become available from adult returns and tag recovery from the fishery. When data on adult contribution become available, these will be compared with our rankings (Table 5). Such a comparison should reveal the utility of the various smolt indices. Ultimately, a suite of measures of smolt quality will be developed; these measures could be weighted for their relative reliability for predicting adult contribution.

The production fish in this study were not released at the same time at all hatcheries. Since river flows, estuarine conditions, and nearshore ocean conditions undoubtedly vary over the time that the fish were released, and since these factors may differentially influence smolt (and adult) survival, it may not be valid to compare adult survival among hatcheries (Francis et al. 1989; Schiewe et al. 1989). Information on rates of downstream migration, estuarine residence, and early ocean survival could supply supplementary information to compare with the smolt quality data. However, such information will not be available.

Another problematic aspect of our study is the relative ranking of the hatcheries (Table 5) and hatchery location. Our rankings suggest that Willamette fish had the highest quality smolts. Willamette is located below Bonneville Dam, whereas the other hatcheries are mid- or upper-river hatcheries. Fish released from Willamette Hatchery do not have to negotiate passage at dams, and this factor alone may favor survival of Willamette fish relative to the other hatcheries in our study. Thus, if the adult contribution of fish released from

Table 5.-- Relative ranking of hatchery groups with regard to expected profile of smolt indicators. Highest ranking = 4; lowest ranking = 1. Parameters that show no ranking, e.g., blood cell counts, had values within the normal range with no differences of major significance. It should be noted that since time-course data are available for Willamette raceway 21B only, ranking of immune competence for all hatcheries is questionable.

Hatchery	Dworshak	Leavenworth	Warm Springs		Willamette	
Raceway:	11-14	42-45	11	13	21A	21B
Parameter						
Fork Lngth	2	1	2	2	3	4
Bod. Wt.	2	1	2	2	3	4
Cond. Fact	1	2	2	2	3	4
SW Sodium	1	3	2	2	4	4
SW Potas.	2	1	3	3	4	4
SW ATPase	1	1	2	2	3	4
FW ATPase	1	1	1	1	2	4
T4	3	2	1	1	4	4
T3	2	3	1			
Insulin	2	3	1			4
Cortisol	3	3	2	1	1	4
Stress factors		-	-	-	-	-
Glucose	-	-	-	-	-	-
Glycogen	2	1	3	3	3	4
Triglycerides	3	2	2	2	1	4
Morph. PC	2	3	2	1	2	4
Skin Guan.	3	2	1	1	3	4
Immun. Resp.	1		2	3	4	4
Blood						
TOTALS	31	29	29	26	40	60

Willamette is higher than that of the other hatcheries, it will be difficult to partition the cause of greater adult contribution between better juvenile passage downstream and better smolt quality. Additional study of smolt indices will be required to resolve conflicting interpretations. In this regard, preliminary analysis of smolt quality data from 1990 suggests that smolt indices show greater development than they did in 1989 at some of the upper-river hatcheries. We anticipate that year-to year variation in smolt development at these hatcheries should provide a wider range of smolt quality to assess the reliability of indices. However, such a comparison should be done cautiously, since comparison of adult contribution of a single hatchery over several years assumes stable conditions of river flows, estuarine conditions, and near-ocean conditions.

It is anticipated that these studies will provide a suite of measurements that can be used to determine appropriate times for release of smolts from the hatcheries. The appropriate time for release would be based on the time when smolts achieve a physiological condition that would maximize their rate of downstream migration and survival. Assessment of smolt quality would be used to refine hatchery practices to improve survival, match the time of smolt releases to high river flows, and reduce the competition between hatchery-released smolts and migrating wild juvenile salmon.

LITERATURE CITED

Barton, B. B., C. B. Schreck, R. D. Ewing, A. R. Hemmingsen, and R. Patino. 1985. Changes in plasma cortisol during stress and smoltification in coho salmon Oncorhvnchus kisutch. Gen. Comp. Endocrinol. 59:468-47 1.

Blackbum, J., and W. C. Clarke. 1987. Revised procedure for the 24 hour seawater challenge test to measure seawater adaptability of juvenile salmonids. Can. Tech. Rep. Fish. Aquat. Sci. No. 1515: l-35.

Bucolo, G., and H. David. 1973. Quantitative determination of serum triglycerides by the use of enzymes. Clin. Chem. 19:475–482.

Clarke, W. C., and J. Blackbum. 1977. A seawater challenge test to measure smolting of juvenile salmon. Fish. Mar. Serv. Res. Dev. Tech. Rep. 705: l- 11.

Dewilde, M. A., and A. H. Houston. 1967. Haemarological aspects of thermo-acclimatory process in the rainbow trout (Salmo gairdneri). J. Fish. Res. Board Can. 23:2267-2281.

Dickhoff, W. W., D. S. Darling, and A. Gorbman. 1982a. Thyroid function during smoltification of salmonid fish. In: Phvlogenetic Aspects of Thyroid Hormone Actions. Institute of Endocrinology, Gunma University eds., Gunma Symposia on Endocrinology, Vol. 19, p. 45-61, Center for Academic Publications Japan, Tokyo.

Dickhoff, W. W., L. C. Folmar, and A. Gorbman. 1978. Changes in plasma thyroxine during smoltification of coho salmon, Oncorhvnchus kisutch. Gen. Comp. Endocrinol. 36:229-232.

Dickhoff, W. W., L. C. Folmar, J. L. Mighell, and C. V. W. Mahnken. 1982b. Plasma thyroid hormones during smoltification of yearling and underyearling coho salmon and yearling chinook salmon and steelhead trout. Aquaculture 28:39-48.

Eales, J. G., M. Hughes, and L. Uin. 1981. Effect of food intake on diel variation in plasma thyroid hormone levels in rainbow trout, Salmo gairdneri. Gen. Comp. Endocrinol. 45:167–174.

Folmar, L. C., and W. W. Dickhoff. 1980. The par-r-smolt transformation (smoltification) and seawater adaptation in salmonids. A review of selected literature. Aquaculture 21:1-37.

Francis, R. C., W. G. Pearcy, R. Brodeur, J. P. Fisher, and L. Stephens. 1989. Effects of the ocean environment on the survival of Columbia River juvenile salmonids. In: “Quality and behavior of juvenile salmonids in the Columbia River estuary and nearshore ocean. Research Plan Final Report, Bonneville Power Administration Project 88-159, 76 p.

Giorgi, A. E., G. A. Swan, W. S. Zaugg, T. Coley, and T. Barila. 1988. Susceptibility of chinook salmon smolts to bypass systems at hydroelectric dams. North Am. J. Fish. Manag. 8:25-29.

Hoar, W. S. 1988. The physiology of smolting salmonids. In W. S. Hoar and D. J. Randall (editors), Fish physiology. Vol XIB Academic Press. San Diego. p. 275-343.

Laidley, C. W., and J. F. Leatherland. 1988. Circadian studies of plasma cortisol, thyroid hormone, protein, glucose and ion concentration, liver glycogen concentration and liver and spleen weight in rainbow trout, Salmo gairdneri Richardson. Comp. Biochem. Physiol. 89A: 495-502.

Nishioka, R. S., G. Young, H. A. Bern, W. Jochimsen, and C. Hiser. 1985. Attempts to intensify the thyroxin surge in coho and king salmon by chemical stimulation. Aquaculture 45:2 15-225.

Parametrix, Inc. 1983 Physiological monitoring of smoltification and stress in mid-Columbian chinook and steelhead, 1983. Draft Report. Bellevue Washington. 54 p.

Patiño, R., C. B. Schreck, J. L. Banks, and W. S. Zaugg. 1986. Effects of rearing conditions on the developmental physiology of smolting of coho salmon. Trans. Am. Fish. Soc.115:828-837.

Plisetskaya, E., W. W. Dickhoff, T. L. Paquette, and A. Gorbman. 1986. The assay of salmon insulin by homologous radioimmunoassay. Fish Physiol. Biochem. 1:35--l 1.

Plisetskaya, E. M., P. Swanson, M. G. Bernard, and W. W. Dickhoff. 1988. Insulin in coho salmon (Oncorhvnchus kisutch) during the parr to smolt transformation. Aquaculture 72:151–164.

Redding, J. M., F. H. Everest and C. B. Schreck. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Trans. Am. Fish. Soc. 116:737-744.

Redding, J. M., C. B. Schreck, E. K. Birks, and R. D. Ewing. 1984. Cortisol and its effects on plasma thyroid hormone and electrolyte concentration in fresh water and during seawater acclimation in yearling coho salmon, Oncorhvnchus kisutch. Gen. Comp. Endcrinol. 56: 146- 155.

Schiewe, M. H., D. M. Miller, E. M. Dawley, R. D. Ledgerwood, and R. L. Emmett. 1989. Quality and behavior of juvenile salmonids in the Columbia River estuary and nearshore ocean. Research Plan Final Report, Bonneville Power Administration Project 88-159, 76 p.

Soivio, A., and E. Virtanen. 1985. The quality and condition of reared Salmo salar smolts in relation to their adult recapture rate. Aquaculture 45:335-343.

Staley, K. B. 1984. Purine deposition in the skin of juvenile coho salmon, Oncorhynchus kisutch. M.S. Thesis, Oregon State University, Corvallis, OR 63 p.

Tripp, R. A., A. G. Maule, C. B. Schreck, and S. L. Kaattari. 1987. Conisol mediated suppression of salmonid lymphocyte responses in vitro. Developmental and Comparative Immunology 11:565-576.

Warren, J. 1989. Augmented fish health monitoring. Annual Report 1988-1989, Project 87-119, 39 p. Bonneville Power Administration.

Wedemeyer, G. A., and D. J. McLeay. 198 1. Methods for determining the tolerance of fishes to environmental stressors. In: “Stress and Fish”, A. D. Picketing, ed. Academic Press, Inc. London. p. 247-275.

Wedemeyer, G. A., and W. T. Yasutake. 1977. Clinical methods for the assessment of the effects of environmental stress on fish health. U.S. Dept. Interior, Fish & Wildlife Service, Technical Paper 89: 1- 18.

Winans, G. A. 1984. Multivariate morphometric variability in Pacific salmon: technical demonstration. Can. J. Fish. Aquat. Sci. 41: 1150-l 159.

Winans, G. A., and R. S. Nishioka. 1987. A multivariate description of change in body shape of coho salmon (Oncorhvnchus kisutch) during smoltification. Aquaculture 66:235-245.

Young, G. 1986. Cortisol secretion in vitro by the interrenal of coho salmon (Oncorhvnchus kisutch): relationship with plasma thyroxine and plasma cortisol. Gen. Comp. Endocrinol. 63: 191-200.

Zar, J. H. 1974. Biostatistical Analysis. Prentice Hall. Englewood Cliffs, NJ. 620 p.

Zaugg, W. S. 1982. A simplified preparation for adenosine triphosphatase determination in gill tissue. Can. J. Fish. Aquat. Sci. 39:215-217.

Zaugg, W. S. 1989. Migratory behavior of underyearling Oncorhvnchus tshawvtscha and survival to adulthood as related to prerelease gill (Na^+-K^+)–ATPase development. Aquaculture 82:339–353.

Zaugg, W. S., and L. F. McLain. 1972. Changes in gill adenosinetriphosphatase activity associated with parr-smolt transformation in steelhead trout, coho, and spring chinook salmon . J. Fish. Res. Board Can. 29:167-171.

APPENDIX 1

Field Notes

GENERAL

Field sampling of the 1987-brood spring chinook salmon for BPA project X9-46 commenced in March 1989 and continued through May. The following describes hatcher) collection procedures, and protocols for collecting blood and tissue samples which were derived by the end of the sampling season. Deviations from these procedures will be described separately for specific hatcheries.

The sample collecting team obtained blood and tissue samples approximately every 2 weeks at each hatchery. Not all tissues were taken on each visit, however. Samples of gill filaments for ATPase, plasma for thyroxine (T_4 and T_3), insulin, cortisol (including secondary stress), and photographs for morphometrics were taken biweekly, whereas skin for guanine, liver for glycogen and triglycerides, blood for electrolytes, glucose, total protein, and smears, and muscle for water content were taken approximately monthly. Saltwater challenge tests were performed once or twice before release (see METHODS) and immune response was measured at Dworshak and Warm Springs NFH, and at the Willamette Hatchery on each biweekly visit (see METHODS).

On the first visit to each hatchery an appropriate work area was found. Specific raceways were identified and subsequent collections were from those raceways. Sufficient plasma for all plasma parameters under investigation was not available from a single fish. Therefore, two 15-fish collections were taken. In addition, another 15-fish sample was obtained for the secondary stress test.

SAMPLING PROCEDURES

Samples taken from, and measurements taken on, each group are outlined below:

Group I — Biweekly (secondary stress); length (mm), weight (g), sex. plasma (cortisol), liver condition.

A suess bucket (a 5-gallon bucket with holes drilled in the sides and bottom) was suspended from a fixture along the wall of a raceway such that the bottom of the bucket was well below the surface of the water. Approximately 15 fish were then dip-netted from the raceway and deposited into a separate bucket of water from which exactly 15 fish were poured, with water, into the stress bucket. The water level was adjusted by raising the stress bucket so that the backs (not the dorsal fin) of the median-sized fish were barely under water. The stress bucket was secured in this position and fish were allowed to remain under those conditions for 1 hour. The test was terminated by placing the fish in a lethal concentration of MS-222 (200 mg/L) after which they were transported rapidly to the work area where lengths and weights were measured and recorded. Each fish was blotted, then the tail was severed with a scalpel blade at the caudal peduncle. Blood was collected in a heparinized Pasteur pipet [prepared prior to field season by filling and emptying each pipet with an ammonium heparin solution (1,000 units/ml) and drying at room temperature]. As blood flow ceased, the pipet containing blood was placed, tip down, in a 400µl polyethylene microfuge tube and blood was allowed to drain. After all 15 fish had been processed. any blood remaining in the pipets was gently blown into the microfuge tube. The tubes were centrifuged in a Beckman Model E microfuge for 3 minutes. The supernatant plasma was drawn out of the individual tubes with an unheparinized Pasteur pipet and placed in a labeled microfuge tube. Plasma was stored on dry ice in the field, then transferred to and stored in a freezer (-20^{o} C) at Cook, Washington until delivery to the appropriate laboratory conducting the analysis. Carcasses were opened, sex determined, and kidneys and livers examined. Total time for processing 15 fish was less than 45 minutes.

Group 11 Biweekly; length, weight, sex, hematocrit, plasma (cortisol, glucose).
Monthly; plasma (electrolytes, total protein), blood (smear).

During the 1 -hour stress challenge, Group II fish used to obtain plasma for cortisol and glucose were collected and processed. Approximately 15 fish were netted from a raceway and deposited in a lethal concentration of MS-222 (200 mg/L). Care was taken not to startle fish in the raceway prior to netting and quickly placing them into the MS-222. Plasma was collected as indicated above for Group I, but these additional steps were added: as blood flow slowed with each fish, a microhematocrit tube (ammonium heparin, 3 units/tube, Kimble) was filled with blood. The tube was plugged with clay, then placed on ice until all 15 fish had been processed. The tubes were then centrifuged in a microhematocrit centrifuge for 3 minutes. and hematocrit values determined and recorded. When collecting monthly samples for plasma elecuolytes and total protein, and for blood smears, the protocol was altered considerably. It became important to collect as much blood as possible from each fish to have sufficient plasma to provide for all assays. Therefore, to prevent reduced blood volumes from fish that had been dead too long, subgroups of 6 to 9 fish were collected at one time. After the first subgroup of fish was processed, the second subgroup (making a total of 15 fish) was collected and processed. Lengths and weights were recorded, the tail severed, and blood collected in an ammonium heparinized Caraway tube (370 µl, Monoject). After the tube was full, a hematocrit tube was filled. If a fish did not yield enough blood to fill a Caraway tube, the hematocrit tube was filled by placing the tip against the end of the Caraway tube and allowing capillary action to fill it. The hematoctit tube was plugged and placed on ice. A blood smear was prepared by spotting a drop of blood from the Caraway tube onto a microscope slide. The blood was smeared across the slide with a second slide and then allowed to air dry. The Caraway tube was capped and placed in a Serofuge. After the first subgroup of fish was finished, the Caraway tubes were centrifuged for 5 minutes in the Serofuge, removed, scored, and broken at the serum-buffy coat interface. The plasma was blown into a labeled 1.5-ml microfuge tube and placed on dry ice. The above steps were repeated for the second subgroup of fish. The 15 microhematocrit tubes were centrifuged for 3 minutes in a hematocrit centrifuge, hematoctits determined, and values recorded. The tubes were then broken at the packed cell-plasma interface, and the plasma was expelled into a 400 μl microfuge tube, frozen on dry ice, and stored for cortisol analysis. Blood smear slides were placed in 100% methanol for at least 15 minutes, removed and placed in slide racks, then stored for later reading. A ventral incision was made, sex, liver, and kidney condition noted.

Group III Biweekly; photographs (morphometrics), thyroid hormones (T_3 and T_4, insulin, and gill ATPase.

Monthly; muscle (tissue water), liver (glycogen, triglycerides), skin (guanine).

This group of 15 fish was collected after the other groups had been sampled. The fish were dip-netted from the raceway, placed in a bucket of water, and carried to the work area. Individuals were taken alive from the bucket, one at a time, killed by a blow to the head, blotted, measured, and weighed. Individuals were placed on a lighted camera stand against a white background. A label containing the date, hatchery, and group number was placed next to the fish, and various morphometric landmarks were marked by placement of pins. A photograph was taken using an Olympus OM-4T camera, f-stop 11, with Kodak TMAX 100 B/W film. Blood was collected and plasma separated as indicated above for Group I fish, with the additional precaution taken of placing the whole blood on ice until all fish had been processed. Gill filaments were trimmed from the lower half of two to four arches (depending on the size of the fish) and placed in a pyrex test tube with 1 ml of SEI (sucrose-EDTA-imidazole). The test tubes were covered with Parafilm and placed on dry ice after the last fish was processed. Samples were transported to the laboratory where they were stored at -80° C until analyzed. A ventral incision was made, and sex and liver condition noted and recorded.

When collecting the monthly samples, which included those for liver glycogen and triglycerides, skin guanine, and muscle water content, along with those listed above. the following procedure was carried out before excising the gill filaments and immediately after collecting the blood: a ventral incision was made and sex and liver condition noted. A 0.10 to 0.20 g piece of liver was cut from the posterior tip of the liver lobe, placed in a tared, labeled vial, and weighed to 0.01 g. About 5 ml of liquid nitrogen was placed in the vial with the liver to quick-freeze the tissue, preserving the glycogen from enzymatic degredation. After the liquid nitrogen had evaporated, the vial was capped and placed on dry ice (within 2 minutes). A second piece of liver (0.05 to 0.1 g) was excised and placed in a labeled test tube (for triglyceride analysis), the tube capped with Parafilm and placed on dry ice. Two parallel incisions were made 1 cm apart, 5 mm deep, midway between the back of the head and the front of the dorsal fin insertion, to a point 5 cm beyond where they were started. A perpendicular incision was made connecting the two parallel lines at the front end. One comer of the skin was grasped with forceps and peeled back toward the tail. A scalpel was used to help separate muscle and fat tissue from the skin. The flap of skin (about 1 x 5 cm) was cut free, placed in a labeled tube, capped with Parafilm, and placed on dry ice for later analysis of guanine. A piece of white muscle (0.1 to 0.2 g) was carved from the area exposed by removal of the skin, placed in a tared, labeled vial, and weighed to the nearest 0.01 g. The vial was then capped and placed on dry ice (for tissue water analysis). All tissue samples were stored at Cook, Washington at -80° C until delivery to the appropriate laboratory. Time to complete sampling was less than 1.75 hours.

Group IV Saltwater challenge.

Saltwater challenges were performed prior to releases. An additional 20 fish were required from each raceway for each challenge. Salt water was made up on site by adding approximately 80 L hatchery water to 2.9 kg Instant Ocean Salts in a 128 L plastic container. The salinity was measured with a refractometer and either water or salt was added to adjust the salinity to a concentration of 30 ppt. The plastic containers were placed or suspended in running hatchery water to maintain the temperature. Water in the container was aerated using an air pump and air stones. Twenty fish were dip-netted from the raceway, placed in a bucket of water and carried to the challenge site, then netted from the bucket and placed into the salt water. The container was covered and fish were maintained under these conditions for 24 hours after which the fish were removed by netting and placed in a bucket containing salt water. Fish were removed one at a time from the salt water, killed by a blow to the head, rinsed in fresh water, weighed, and measured. Plasma was collected as indicated for Group I above. Gill filaments were excised, placed in SEI. and held on dry ice until arrival at the laboratory where they were stored at -80° C until analyzed for ATPase activity. A ventral incision was made and the sex and liver condition noted. All mortalities occurring during the challenge were counted, weighed, and measured.

SAMPLED FISH

The following tables list, for individual fish, fork lengths (mm), weights (g), sex (F = female, M = male, Md = developing male, Mp = fully developed, precocious male), and abnormal liver condition (Lp = pale liver, Lm = mottled liver, also An = anemic as assessed by light-colored blood). Also noted are any variations from the general sampling procedure and other observations that may have affected some of the parameters being measured, including water temperature at the time of sampling and time of day at which fish from the stress challenge were killed for processing (for use in approximating the time at which the various samples were collected). The raceway (RWY) number for each group is given.

Dworshak	Md=developing male; Mp=fully developed, precocious male; An=anemic												
Lp=pale liver; Lm=mottled liver; T=coded wire tag; B=branded													
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/8/89	Group 1	Rwy 11	9 50 pm temp=5				3/8/89	Group II	Rwy 11	Temp = 5			
1	150	37 5	M		1 111		1	114	16 2	F	29	1 093	
2	125	21 5	M		1 101		2	134	25 5	M	33	1 06	
3	137	26 5	M		1 031		3	119	18 2	F	32	1 08	
4	161	49 6	F		1 189		4	119	18 7	M	40	1 11	
5	122	[illegible]	F		1.096		5	133	25 4	M	32	1.08	Lm
6	137	27 7	F		1 077		6	125	21 1	F	38	1 08	
7	135	27 2	F		1 106		7	118	18 2	F	34	1.108	
8	109	13 4	F		1 035		8	125	22	M	39	0 932	
9	99	10 3	F		1 062		9	132	27 8	M	34	1.209	
10	130	23	F		1 047		10	120	19 3	F	34	1 117	
11	131	23 9	F		1 063	Lp	11	116	17 1	F	35	1 096	
12	161	66 9	Md		1 128	Lp	12	119	18.3	M	42	1.086	
13	127	22 [illegible]	F		1 089	Lm	13	119	19 1	F	39	1 113	
14	121	20	F		1 129		14	119	18 6	M	638	~~1.1041~~	
15	104	12 3	F		1 0931		15	180	61 7	M	33	1 058	
Ave	131	26 8			1 09		SD	126	23 1		35	1 088	
SD	21	14 8			0 041		SE	16	11 2		4	0 056	
SE	5	3 8			0 011			4	2 9		1	0.0141	
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3·8/89	Group III	Rwy 11	temp=5				3/15/89	Group I	Rwy 11; 11 40 am, temp=5				
1	120	19 3	M		1 117		1	110		F			Lm
2	140	33 4	Md		1 217		2	118	17 7	F		1 077	
3	131	24 9	F		1 108		3	117	16 7	F		1 043	
4	137	29 8	M		1 159		4	118	17 6	M		1 071	
5	1211	18 7	M		1 056	descaled	5	134	2 7 [illegible]	M		1.135	
6	12	19 4	M		1 043	Lp	6	118	19 4	F		1.01	
7	1391	31 4	M		1 169		7	115	15 5	F		1 019	Lm
8	125	21 9	F		1 121		8	119	18 3	M		1 086	Lp
9	128	22 7	F		1 082		9	121	18 4	F		1 039	
10	138	28 4	F		1 081		10	116	18	F		1.153	
11	125	21	M		1 075		11	121	18 7	M		1 056	Lm
12	145	36 1	Md		1 184		12	132	23 3	M		1 013	
13	129	24 3	F		1 132		13	130	24 3	F		1.106	
14	124	20 7	M		1 086		14	140	29 3	Md		1 068	Lm
15	121	1 8 3	M		1 033		15	129	27 4	F		1 276	
Ave	130	24 7			1 111		Ave	123	20 7			1 082	
SD	8	5 8			0 54		SD	8	4 7			0.07	
SE	2	1 5			0 014		SE	2	1 2			0.019	
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3·15/89	Group II	Rwy 11	temp=			subgrp #	3/15/89	Group III	Rwy 11: temp=				
1	124	21 8	Md	30	1 143	1	1	110	15 8	F		1 187	
2	128	22 1	M	27	1 054	Lm 1	2	119	19 9	Md		1 181	
3	120	18 7	M	33	1 082	1	3	127	22 3	F		1 089	
4	126	22 5	M	24	1 125	1	4	178	68 1	Md		1 207	
5	123	21 6	F	34	1 161	1	5	138	27 8	F		1 058	
6	132	24 6	Md	38	1 07	1	6	132	26 2	Md		1 139	
7	110	15 8	M	34	1 187	1	7	121	18 8	F		1 061	
8	133	26 2	Md	37	1 114	1	8	112	15 6	F		1.11	
9	130	23	F	24	1 047	1	9	119	18 9	F		1 122	
10	132	24 6	M	34	1 07	1	10	108	14	M		1 111	
11	1241	22 5	F	25	1 18	2	11	120	20	F		1 157	
12	120	17 9	M	34	1 036	2	12	107	14 2	M		1.159	Lm
i 3	119	20 6	Md	31	1 222	2	13	127	25 3	Md		1 235	
i 4	132	24 5	Md	30	1 065	2	14	170	50 5	M		1 028	
15	120	19 4	M	30	1 123	2	15	147	32 7	F		1 029	
Ave	125	21 7		31	1 112		Ave.	129	26			1 125	
SD	6	2 8		5	0 057		SD	21	14 9			0 064	
SE	2	0 7		1	0 015		SE	6	3 8			0 016	

Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/15/89	Group I	Rwy 12	4 00pm temp=			
1	121	21 3	M		1 202	
2	115	17 2	M		1 131	
3	117	18 4	M		1 149	
4	119	18 5	M		1 098	
5	1741	71 2	F		1 112	
6	119	17 8	F		1 056	An
7	127	21 2	M		1 035	An
8	130	24 2	F		1 102	
9	139	30 2	Md		1 125	
10	141	29 3	Md		1 045	
11	132	27	F		1 174	
12	135	29 1	M		1.183	
13	136	30 3	F		1 205	
14	141	34 6	M		1 234	
15						
Ave	128	24 3			1 132	
SD	9	5 7			0 062	
SE	2	1 5			0 017	

Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/15/89	Group II	Rwy 12. temp=				subgrp #
1	117	17 2	M	28	1 074	An 1
2	128	23 9	M	28	1 14	1
3	140	34 1	Md	26	1 243	1
4	128	24 5	M	36	1 168	1
5	121	20 1	F	33	1 135	1
6	160	52.6	F	30	1 284	1
7	135	28 2	M	35	1 146	1
8	133	26 2	F	36	1 114	1
9	165	52.5	Md	27	1 169	1
10	115	17 1	F	22	1 124	2
11	114	18	F	19	1 215	2
12	115	17 8	M	16	1 17	2
13	125	22 7	M	26	1 162	2
14	124	20 3	Md	22	1 065	2
15	161	45 4	Md	29	1 088	2
Ave.	132	28		28	1 153	
SD	17	12 4		6	0 06	
SE	4	3 2		2	0 016	

Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/15/89	Group III	Rwy 12	temp=			
1	121	19 7	Md		1 112	
2	110	15 6	M		1 172	
3	161	50 2	Md		1 203	
4	141	31 6	F		1 127	
5	115	17 3	F		1 138	
6	108	14 9	F		1 183	
7	127	23 8	M		1 162	
8	126	21 8	F		1 09	
9	122	21 6	M		1 19	
10	113	15 8	F		1 095	
11	134	28 8	M		1 12	
12	118	18 4	F		1 12	
13	135	34	F		1 382	An ,Lm
14	125	20	F		1 024	
15	157	43 9	F		1.134	
Ave	128	25 2			1.15	
SD	16	10 6			0 0791	
SE	4	2 7			0 02	

Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/16/89	Group I	Rwy 13. 8 45 am, temp=				
1	1221	21 4	F		1.179	
2	118	17 4	F		1 059	
3	117	16 3	F		1 018	Lm
4	115	17 2	F		1 131	An
5	114	16 8	M		1.134	
6	110	14 2	F		1 067	
7	110	14 7	M		1 104	
8	110	13 7	F		1 029	
9	122	19 6	M		1 079	
10	132	24.1	F		1.048	
11	130	24 1	F		1 097	
12	130	25	M		1 138	
13	125	22 2	F		1.137	
14	139	31 1	Md		1 158	
15	147	38 1	F		1 199	
Ave	123	21 1			1.105	
SD	11	6 8			0 055	
SE	3	1 7			0 014	

Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/16/89	Group II	Rwy 13	temp=			subgrp #
1	134	26 1	F	28	1 085	1
2	125	21 4	M	32	1 096	1
3	124	22 9	F	37	1 201	1
4	127	23 1	F	33	1 128	Lm 1
5	114	16 6	F	35	1 12	1
6	117	17 8	M	39	1 111	1
7	141	34 7	Md	29	1 238	1
8	129	25	M	35	1 165	1
9	136	30	F	36	1 193	1
10	150	38 2	F	41	1 132	1
11	1 1 3 1	15 3	M	23	1 16	Lm 2
12	112	16 2	M	30	1 153	2
13	121	19 2	M	28	1 084	2
14	124	21 7	F	32	1 138	2
15	134	25 4	M	30	1 056	2
Ave	127	23 6		33	1 131	
SD	11	6 7		5	0 052	
SE	3	1 7		1	0 014	

Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/16/89	Group III	Rwy 13. temp=				
1	1231	21 2	M		1 1391	
2	108	17 7	F		1 088	
3	133	27 2	F		1 156	
4	113	16 1	M		1 116	
5	126	21 6	F		1 08	
6	137	31 9	Md		1 241	
7	98	10 5	F		1.116	
8	111	17 2	F		1 258	
9	130	24 6	M		1 12	
10	127	24 6	M		1 201	
11	130	28	F		1 302	
12	115	16 9	F		1.111	
13	120	18 9	F		1 094	
14	132	25.4	F		1 104	
15	146	36 3	F		1.166	
Ave	123	22 31			1 153	
SD	13	7			0 068	
SE	3	1 8			0 018	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/16/89	Group I	Rwy 14	11 45 am temp=				3/16/89	Group II	Rwy 14: temp=				subgrp #
1	120	20 2	F		1 169		1	120	18.7	F	10	1 082	T,1
2	122	21 2	F		1.167	T,B	2	127	23 7	M	30	1.157	T,B, 1
3	112	15	F		1 068	An	3	123	21 1	M	38	1.134	T,B, 1
4	120	18 3	F		1 059	T,B	A	118	17.1	F	26	1 041	T B,Lp, 1
5	121	20 2	M		1.14	T,B	5	135	27 4	F	33	1.114	T B 1
6	118	17.6	F		1.071	Lm	6	129	24.8	F	37	1.155	T,B, 1
7	115	16 9	M		1 111	T,B	7	120	18 9	F	19	1 094	T,B, 1
8	125	22 2	M		1.137	T,B	8	120	18 9	F	43	1.094	T,B, 1
9	120	19.7	Md		1 14	T,Lm	9	146	37 8	Md	41	1 215	1
10	123	20 3	M		1 091	T	10	125	21.5	M	19	1 101	2
11	123	21.2	F		1.139	T,B,An	11	123	20.9	M	15	1 123	2
12	135	27.5	M		1 118		12	129	24 1	M	28	1 123	2
13	136	28	F		1.113		13	133	26 9	M	20	1.143	2
14	129	26 2	M		1 22	T,B	14	131	24 9	Md	24	1 108	B, 2
15	137	28.1	F		1 093	T	15	160	50 2	Md	29	1 223	B, 2
Ave	124	21 5			1.122		Ave.	129	25 1		27	1.127	
SD	7	4 2			0 044		SD	11	8 6		10	0 048	
SE	2	1.1			0.011		SE	3	2.2		3	0.012	
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/16/89	Group III	Rwy 14	temp=				3/27/89	Group I	Rwy 11 4 20 pm, temp=				
1	140	29 9	Md		1 09	T,B	1	110	14	M		1.052	
2	128	22 9	M		1 092		2	130	24 4	F		1 111	
3	112	15	M		1 068	T,B	3	112	16 7	Md		1.189	
4	124	21 7	F		1 138		4	116	18 1	M		1.16	An
5	131	26 9	F		1 197	T B	5	123	22 3	Md		1 198	
6	135	27.5	F		1 118	T,B	6	122	21 2	M		1 167	
7	115	17 8	Md		1 17		7	123	20	F		1 075	
8	105	12 6	M		1.088	T,B	8	122	20 7	F		1.141	
9	117	18.3	Md		1.143	T,B,Lm	9	124	21	F		1.101	
10	131	26 5	M		1.179	T,B	10	130	22 4	M		1 02	
11	121	20.1	F		1 1351T.B		11	127	23.7	M		1.157	
12	119	19 3	F		1.145	T	12	131	26 1	F		1 161	
13	121	19 4	Md		1 095	T,B	13	134	29 8	Md		1.239	
14	134	29 3	Md		1 218	T,B	14	137	27 9	Md		1.085	
15	166	52 9	F		1 156	T,B	15	141	22 5	Md		1.159	
Ave	127	24			1 135		Ave.	125	22 7			1.134	
SD	14	9 5			0 044		SD	9	4 9			0.059	
SE	4	2 5			0 011		SE	2	1 3			0.015	
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/27/89	Group II	Rwy 11					3/27/89	Group III	Rwy 11				
1	123	21 4	M	13	1 15		1	120	20 3	F		1 175	An
2	134	26 9	M	32	1.118		2	131	24 2	F		1.076	
3	120	18 3	F	34	1 059		3	138	28 6	Md		1 088	
4	120	19 3	Md	30	1.117		4	149	39.3	Md		1 188	
5	105	13 . 3	F	30	1.149		5	150	38.3	Md		1.135	
6	1241	21.1	F	34	1.107		6	123	19 1	M		1.026	
7	131	24 4	Md		1 085		7	124	22	F		1 154	
8	140	30.2	Md	36	1.101		8	125	23	Md		1 178	
9	135	28 4	F	32	1 154		9	109	15 3	M		1.181	
10	133	25 5	F	35	1 084		10	115	16.3	F		1 072	An
11	116	17 7	M	29	1 134		11	119	19 3	F		1.145	
12	123	20 8	F	39	1 118		12	113	15 9	M		1.102	
13	124	21 3	F	35	1 117		13	113	16 5	M		1.145	
14	127	23 7	M	35	1 157		14	135	26 3	M		1 069	
15	204	9 7	Md	40	1143		15	152	37	Md		1.054	
Ave	131	27 3		32	1119		Ave.	128	24 1			1.119	
SD													
SE	22 6	19 51 8		62	0029 0007		SE	14 4	83 21			0.053 0 014	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/27/89	Group IV	Rwy 11					3/27/89	Group I	Rwy 12				
1	120	15 4	M		0 891	dead	1	117	18 2	F		1.136	
2	113	14 6	Md		1 012	moribund	2	113	15 3	F		1 06	
3	115	15 1	F		1 028	moribund	3	117	17 1	M		1 068	
4	107	12 5	M		1 02	moribund	4	113	17 1	F		1.185	
5	103	10.6	M		0 97		5	116	17 3	F		1.108	
6	111	13 8	F		1 009		6	125	23 4	Md		1.198	
7	129	22	F		1 025		7	123	21.8	F		1.171	
8	120	17.1	F		0 99		8	121	20.7	F		1.168	
9	112	13 8	F		0 982		9	127	24 4	F		1.194	
10	122	19 2	F		1 057		10	130	25 2	M		1 147	
11	118	17	M		1 035		11	128	23 6	M		1 125	
12	133	24 1	M		1 024		12	125	21	M		1 075	
13	120	17 4	F		1 007		13	130	23 9	Md		1 088	An
14	105	11 7	M		1 011		14	138	29 9	M		1 138	
15	119	17 2	M		1 021		15	168	51 9	Md		1 095	
16	119	16.1	Md		0 955		Ave.	126	23 4			1 13	
17	120	17 1	M		0 99		SD	14	8 8			0 046	
18	132	23	F		1		SE	4	2 3			0.012	
19	136	26	M		1 034								
201	148	37 1	M		1 144								
Ave	120	18			1.01								
SD	11	6 1			0 048								
SE	2	1 4			0 011								

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3 27/89	Group II	Rwy 12					3 27 89	Group III	Rwy 12				
1	117	15 4	F	29	0 962		1	122	19 5	M		1 074	
2	128	21 4	M	30	1 02		21	13:3	26 8	F		1 139	
3	120	19.8	F	21	1 146		3	127	23 4	F		1 142	
4	119	19 3	F	15	1 145		4	133	26 7	Md		1 135	
5	123	21.7	F	29	1 166		5	163	48 4	Md		1 118	An
6	137	30 2	Md	37	1 174		6	128	22 5	F		1 073	
7	124	21 3	F	30	1 117		7	105	12 9	M		1 114	
8	128	22.4	F	36	1 068		8	140	31 3	Md		1 141	
9	125	23	M	28	1 178		9	124	21 8	M		1 143	
10	141	33 3	Md	18	1 188		10	119	21	F		1 246	
11	121	18 1	F	35	1 022		11	125	21 6	F		1.106	
12	128	20 6	M	7	0 982		12	115	16 7	F		1 098	
13	126	21 5	F	35	1 075		13	140	29 1	F		1 06	
14	143	33 7	F	13	1 152		14	132	25 9	M		1 126	
15	184	67 3	F	20	1 08		15	146	36 8	F		1 182	
Ave	131	25 9		26	1 098		Ave	130	25 6			1 127	
SD	17	12 6		9	0 075		SD	14	8 6			0 046	
SE	4	3 3		2	0 019		SE	4	2 2			0.012	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3 27 89	Group IV	Rwy 12					3.28.89	Group I	Rwy 13	8 20 am			
1	122	17 6	M		0 969		1	100	11 3	F		1 13	
2	168	49 8	F		1 05	An	2	116	18 3	M		1 172	
3	130	22 6	F		1 029		3	111	15 1	F		1 104	
4	116	14 1	F		0 903		4	102	10 8	M		1 018	
5	121	17.5	M		0 988		5	115	16 8	F		1 105	
6	134	22 4	M		0 931		6	128	24	F		1 144	
7	132	23 1	M		1 004		7	114	15 6	Md		1053	
8	118	16 5	M		1 004		8	122	19 9	M		1096	
9	134	23 3	Md		0 968		9	131-1	19 3	F		1 117	
10	135	26 8	Md		1 089	An	10	122	20	F		1 101	
11	1331	22 5	M		0 956	An	11	120	19 5	F		1 128	
121	1451	32 6	F		1069		12	125	21 9	M		1 121	
13	140	29 9	M		1 09	An	13	128	24 6	F		1173	
14	165	46 4	F		1033		14	130	24 3	M		1106	
15	111	15 6	F		1 141	Dead	15	133	24 5	M		1 041	
16	112	15	M		1 068	Dead	Ave	119	19 1			1 107	
17	106	11 6	F		0 974	Dead	SD	10	4 5			0 044	
18	115	15 7	M		1 032	Dead	SE	2	1 2			0 011	
19	114	15 5	F		1 046	Dead							
20	123	18 6	F		1								
Ave	129	22 9			1 017								
SD	17	10 2			0 059								
SE	4	2 3			0 015								

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3 28·89	Group II	Rwy 13					3/28/89	Group III	Rwy 13				
1	133	24 8		32	1 054		1	125	20 1	F		1 029	
2	121	19 7		28	1 112		2	124	20 8	M		1 091	
3	120	20 4		26	1 181		3	118	18 2	F		1 108	
4	146	35 5		35	1 141		4	121	20 3	F		1 146	
5	137	32 1		32	1 248		5	115	17 2	M		1 131	
6	117	18 2		30	1 136		6	133	24 7	F		1 05	
7	143	3 2		30	1 094		7	119	18 9	F		1 122	
8	151	38 2		34	1 11		8	158	44 6	Md		1 131	
9	148	35 9		35	1 107		9	121	19 1	M		1 078	
10	135	31 7		35	1 288		10	125	20 2	F		1 034	
11	154	40 2		34	1 101		11	111	15 2	F		1 111	
12	147	37 7		33	1 187		12	125	22	F		1 126	
131	157	5			1		1					1 126	
14	1521	39 103.71		37	1 13		14	125	22 5	M		1 098	
15	189	[illegible] 3		35	1 204		15	169	[illegible] 2	Md		1 164	
SD	143	15 RI		33	1 106		Ave	1281	24 1			1 103	
	18	3		3	073		SD	16	11 1			0 04	
SE	5	4		1	0 019		SE	4	7 9			0 01	
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3/28/89	Group IV	Rwy 13					3/28/89	Group I	Rwy 14 1040 am temp=				
1	117	16 2	M		1 011		1	115	15 6	F		1026	T B
3	135	28 5	F		1 036	An	3	121	18 6	F		1 093	T,B
4	122	18 8	F		1 035		4	116	16 5	M		1 057	T B
5	120	17 1	M		0991		5	1181	16 4	M		0 998	T B
6	129	23 2	F		1 081		6	123	19	M		1 021	An
7	150	33 4	F		0 99		7	1 3 0	1 21 5	F		0 979	
8	127	20 6	M		1 006		8	131	2 5 .2	M		1 121	
9	127	20 2	F		0 986		9	124	20 1	M		1.054	T.B
10	119	18 5	F		1 098		10	118	19 4	F		1 181	T,B
11	145	33 1	M		1 086		11	125	21 9	F		1.121	T B
12	121	16 8	M		0 948		12	129	24 4	M		1.137	
13	119	17 4	F		1 033		13	135	24 8	F		1 008	T B
14	122	20 7	M		1 14		14	144	33 3	M		1 115	T,B,Lm
15	133	24 8	F		1 054		15	165	52 3	Md		1 164	
16	131	24 3	Md		1 081		Ave	127	22 8			1 075	
17	125	20	F		1 024		SD	14	9 6			0 063	
18	137	27 2	Md		1 058		SE	4	2 5			0 016	
19	124	18	M		0 944								
20	114	15 2	F		1 026	Dead							
Ave	127	21 5			1 03								
SD	9	5 2			0 051								
SE	2	1 2			0 011								
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm)	Wt (g)	Sex	Hct	Cond	Other
3·28/89	Group II	Rwy 14					3/28/89	Group III	Rwy 14				
1	122	20		26	1 101	T,B	1	115	16 5	M		1.085	An
2	125	20 9		21	1 07		2	119	17 4	F		1.033	An
3	139	29 1		36	1 084	T	3	133	25 8	M		1 097	T,B
4	130	24 1		32	1 097	T B	4	139	30 7	F		1 143	
5	175	20 4		32	1 044	T B	5	126	23 4	F		1.17	T,B
6	133	23 3		38	0 99		6	126	20 7	M		1 035	T
7	123	20		27	1 075	T,B	7	139	29 8	M		1 11	
8	135	26 7		23	1 085	T,B	8	127	22 2	Md		1 0841	T.B
9	135	26 9		21	1 093	T,B	9	127	21 9	F		1 069	T,B
10	135	27 9		29	1 134	T,B	10	146	32 3	M		1.038	T,B,An
11	130	22 9		27	1042		11	131	25.1	F		1.117	
12	122	20 8		24	1 145	T,B	12	120	18 9	M		1.094	T,B
13	122	20 6		36	1 134		13	134	26	F		1 081	
14	121	19 6		21	1 106	T	14	135	26 6	F		1 081	
15	147	38		44	1 196		15	135	27 8	F		1 13	T,B,An
Ave	130	24 1		29	1.093		Ave.	130	24 3			1.091	
SD	8	5		7	0 049		SD	6	4 8			0 039	
SE	2	1 3		2	0 01:3		SE	2	1 2			0 01	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other							
3/28/89	Group IV	Rwy 14											
1	125	21 4	F		1 096	T,B,Lm							
2	130	23 5	F		1 07	T,B							
3	128	21 9	F		1 044	T,B							
4	120	18 6	F		1 076	An							
5	127	21 1	F		1 03	T							
6	117	16 5	F		1 03	T,B,An							
7	136	25	M		0 994	T,B,Lm							
8	132	26 3	M		1.143	T							
9	136	25	Md		0 994								
10	116	15 6	F		0 999	T,B							
11	122	18 2	M		1 002	T,B							
12	123	19 1	M		1.026	T							
13	118	15 3	F		0.931								
14	133	24	M		1 02	T							
15	120	17 9	F		1 036	T,B							
16	131	23 4	F		1 041								
17	123	18 9	F		1.016	T,B							
18	125	21 7	F		1.111								
19	121	18 1	F		1 022	T,B							
20	120	17 4	F		1 007	T,B, Dead							
Ave	125	20 4			1 034								
SD	6	3 3			0 047								
SE	2	0 7			0 011								

Leavenworth		Md=developing male; Mp=fully developed, precocious male; An=anemic											
Lp=pale liver; Lm=mottled liver; T=coded wire tag; B=branded													
Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 7·89	Group 1	Rwy 49	1 30 pm temp=2				3·7/89	Group II	Rwy 49				
1	136	26 4	M		1 05	Most	1	149	32 6	M	34	0 986	Most
2	120	17 9	F		1 036	had pale	2	111	14 9	F	42	1 089	had
3	110	14 5	M		1 089	livers	3	155	35 9	Md	36	0 964	pale
4	109	13 6	M		1 05		4	136	24 2	Md	49	0 962	livers
5	110	13 9	M		1 044		5	128	23 7	F	45	1 13	
6	111	14 6	M		1 068		6	112	14.5	M		1 032	
7	104	12 5	F		1 111		7	127	20 7	F	40	1 011	
8	117	17 3	F		1 08		8	122	20 7	Md	41	1 14	
9	110	14 9	M		1 119		9	115	17 4	M	39	1 144	
10	127	23 1	Mp		1 128		10	119	18 5	F	44	1 098	
11	130	23 2	F		1 056		11	112	14 2	F	41	1 011	
12	149	34 5	Md		1 043		12	117	17 3	M	42	1 08	
13	123	20 4	M		1 096		13	110	14 4	F	38	1 082	
14	142	32 4	F		1 132		14	113	15 7	M	40	1 088	
15	157	36 5	F		0 943		15	110	14 5	M	43	1 089	
Ave	124	21 1			1 07		Ave	122	20		41	1 06	
SD	16	8 1			0 048		SD	14	6 7		4	0 062	
SE	4	2 1			0 012		SE	4	1 7		1	0 016	
Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 7 89	Group III	Rwy 49					3/14/89	Group I	11 00am temp=4 5 Rwy 45				
1	124	21 8	M		1 143	Most	1	107	13 2	M		1 078	
2	132	2 4 1	F		1 048	had pale	2	112	14 2	M		1 011	
3	151	40 3	F		1 171	livers	3	123	19 8	M		1 064	
4	115	15 4	F		1 013		4	115	16 3	M		1 072	
5	124	20 6	F		1 08		5	108	13 3	M		1 056	
6	113	16	F		1 109		6	112	15 6	M		1 11	
7	140	29 6	Md		1 079		7	105	11 9	M		1 028	
8	111	16	M		1 17		8	115	16 9	F		1 111	
9	141	24 6	F		0 878		9	106	12 7	F		1 066	
10	129	23 1	M		1 076		10	112	15 4	F		1 096	
11	110	14	F		1 052		11	103	11 8	F		1 08	
12	149	35 4	M		1 07		12	110	14 7	F		1 104	
13	108	13 3	M		1 056		13	122	20 4	M		1 123	
14	113	15 8	M		1 095		14	135	25 3	M		1 028	
15	134	26 1	F		1 085		15	128	25 1	M		1 197	
Ave	126	22 4			1 075		Ave	114	16 4			1 082	
SD	15	8			0 07		SD	9	4 4			0 046	
SE	4	2.1			0 018		SE	2	1 1			0 012	
Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3·14 89	Group II	Rwy 45	temp=4 5 Subgrp #				3.14·89	Group III	Rwy 45	temp=4 5			
1	112	14 5	M	31	1 032	an 1	1	116	17.1	M		1 096	Most
2	113	16 3	Md	33	1 13	1	2	114	15 9	F		1 073	had
3	123	20 2	M	33	1 086	1	3	152	35 9	Md		1 022	pale
4	106	12	M	33	1 008	1	4	123	20 5	F		1 102	livers
5	122	19 6	M	30	1 079	1	5	117	18	F		1 124	
6	137	26 4	F	31	1 027	1	6	147	34 4	F		1 083	
7	122	19 9	Md	39	1 096	1	7	118	18 1	M		1 102	
8	147	32 7	Md	36	1 029	1	8	112	15 2	M		1 082	
9	162	48 6	Md	38	1 143	1	9	118	19 3	F		1 175	
10	163	46	Md	32	1 062	1	10	140	27 9	Md		1 017	
11	117	17 1	M	29	1 068	2	11	120	19 2	F		1 111	
12	117	17 5	F	27	1 093	2	12	125	21 7	F		1 111	
13	116	18	M	31	1 153	2	13	124	21 9	M		1 149	
14	111	15 7	F	31	1 148	2	14	120	18 9	M		1 094	
15	138	28	M	30	1 065	2	15	110	14 8	M		1112	
Ave	127	23 5		32	1 081		Ave	124	21 3			1 097	
SD	18	11 1		3	0 047		SD	[illegible]	3 [illegible]			0 041	
SE	5	291		1	0 012		SE	3	171			0 01	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 14/89	Group I	Rwy 44	8 10am	temp=4.5		
1	1141	16	M		1 08	
2	112	15 3	Md		1 089	
3	115	17 7	Md		1 164	
4	115	15 7	F		1 032	
5	115	17 9	F		1 177	
6	123	21	F		1 129	
7	109	15 3	F		1 181	
8	112	16 7	F		1 189	
9	122	20 5	F		1 129	
10	107	12 4	F		1 012	
11	121	21 1	F		1 191	
12	130	25 5	M		1 161	
13	125	19 8	M		1 014	
14	136	28 6	Md		1 137	
15	147	32 3	F		1 017	
Ave	120	19 7			1 113	
SD	11	5 4			0 068	
SE	3	1 4			0 017	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/14/89	Group II	Rwy 44	temp=4 5			
1	117	169	F	33	1 055	an 1
2	108	[illegible]	M	34	1 119	1
3	110	14 9	F	31	1 119	1
4	116	17 1	Md	35	1 096	1
5	116	16 1	F	33	1 031	1
6	132	26 3	M	34	1 143	1
7	112	14 2	Md	36	1 011	1
8	105	13 5	F	31	1 166	2
9	104	12 2	F	30	1 085	2
10	119	17 8	F	30	1 056	2
11	119	18 8	M	31	1 116	2
12	110	14 8	M	34	1 112	2
13	121	19 9	M	32	1 123	2
14	1381	29 2	F	33	1 111	2
15	138	29 3	Md	34	1 115	2
Ave	118	18 3		33	1 097	
SD	11	5 6		2	0 042	
SE	3	1 4		1	0 011	

Fish #	FL (mm	Wt (g	Sex	HCT	Cond	Other
3 14 89	Group III	Rwy 44	temp=4 5			
1	117	19 1	M		1 193	
2	110	15 1	F		1 134	
3	116	17 8	F		1 14	
4	120	19 3	Mp		1 1171	
5	144	33 4	F		1 119	
6	137	27 8	Md		1 081	
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	
7	142	13 3	M		1 05[illegible]	
9	114	15 8	F		1 066	
10	121	19 7	M		1 112	
11	120	19 4	M		1 123	
12	158	40 6	M		1 029	
13	118	18 1	M		1 102	
14	115	16	F		1 052	
15	135	27	F		1 097	
Ave.	125	22 2			1 098	
SD	15	7 8			0 043	
SE	4	2			0 011	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 13 89	Group I	Rwy 43	5 00pm	temp=4 5		
1	105	12 1	F		1 045	
2	112	15 8	M		1 125	
3	105	13 4	F		1 158	
4	103	11 8	M		1 08	
5	102	11 2	F		1 055	
6	107	12 4	F		1 012	
8	108	14 0	M		1 119	
9	109	13 2	M		1 019	
10	116	16 4	M		1 051	
11	128	25 5	Md		1 216	
12	132	24 7	Md		1 074	
13	135	26 8	Md		1 089	
14	137	30 6	F		1 19	
15	147	34 3	Md		1 08	
Ave	117	18 5			1 091	
SD	15	7 7			0 06	
SE	4	2			0 015	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/13·89	Group II	Rwy 43	temp=4 5			subgroup
1	106	11 9	M	27	0 999	an 1
2	110	14 5	F	36	1 089	1
3	109	14 2	F	35	1 097	1
4	113	14 9	M	41	1 033	1
5	102	11 7	Mp	39	1 103	1
6	122	19 1	Md	34	1 052	1
7	157	40 8	Md	39	1 054	1
8	163	49 3	F	33	1 138	1
9	102	11 4	F	33	1 074	2
10	101	10 3	F	39	1	2
11	97	9 9	F	29	1 085	2
12	114	15 2	F	38	1 026	2
13	110	13 7	F	331 -	1 029	21
14	107	12 8	F	37	1 045	2
15	113	15 3	F	33	1 03	2
Ave	115	17 7		35	1 059	
SD	19	11 5		4	0 0391	
SE	5	3		1	0 01	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/13/89	Group III	Rwy 43	temp=4 5			
1	11					
2	1 14	15 6	M		1 053	
3	1100	7	F		1 17	
4	1331	27 9	F		1 186	
5	110	14 4	F		1 082	
6	128	24 1	F		1 149	
7	115	15 4	M		1 013	
8	159	38 2	F		0951	
9	124	23	Md		1 206	
10	140	31 7	F		1 155	
11	110	15 6	F		1 1731	
12	112	15 3	F		1 089	
13	118	19	M		[illegible]	
14	115	17 3	M		1 138	
15	157	42 3	M		1 093	
Ave	123	221			1 12	
SD	17	921			0 0731	
S	4	2 4			0 019	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/13/89	Group I	Rwy 42	1 15pm	temp=4 5		
1	127	22 3	F		1 089	
2	106	13	F		1 092	
3	116	17 9	M		1 147	
4	123	20 1	M		1 08	
5	123	20 4	F		1 096	
6	120	18.8	M		1.088	
7	119	18.6	F		1 104	
8	116	17 4	F		1 115	
9	120	17 6	M		1 019	
10	110	13 6	F		1 022	
11	111	15 3	M		1.119	
12	108	13	F		1 032	
13	105	13.2	F		1.14	
14	112	15 4	M		1 096	
15	115	15 9	M		1 045	
Ave	115	16 8			1 086	
SD	7	2 9			0 04	
SE	2	0 8			0 01	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/13/89	Group II	Rwy 42	temp=4 5			
1	159	38 2	M	35	0 95	
2	121	19 6	M	35	1 106	
3	170	47 4	F	42	0 965	
4	119	18 6	Md	41	1 104	
5	147	34 8	Md	40	1 096	
6	132	24 6	M	42	1 07	
7	115	16	M	48	1 052	
8	120	19.1	F	43	1.105	
9	114	15.5	F	35	1 046	
10	119	18 1	F	46	1 074	
11	110	14.9	F	43	1.119	
12	121	18 6	F		1 05	
13	117	16 8	M	44	1.049	
14	112	16	F	40	1 139	
15	110	14 9	M		1.119	
Ave	126	22 2		41	1 07	
SD	18	9 9		4	0 054	
SE	5	2.6		1	0 014	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/13/89	Group III	Rwy 42	temp=4 5			
1	133	26	F		1 105	
2	115	16 5	F		1 085	
3	118	17.4	Md		1.059	
4	153	41 2	F		1 15	
5	115	15 2	M		0 999	
6	103	11.5	F		1.052	
7	116	16 2	F		1 038	
8	142	30 5	Md		1 065	
9	109	14.7	F		1.135	
10	107	13.5	Mp		1 102	
11	130	23.6	F		1 074	
12	118	17.6	M		1 071	
13	158	42.1	F		1 067	
14	120	18	F		1 042	
15	157	37.3	M		0 964	
Ave.	126	23.1			1 067	
SD	18	10.1			0 048	
SE	5	2.6			0.012	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/29/89	Group I	Rwy 42	2.15pm	temp=4		
1	125	21.9	M		1.121	
2	115	17	M		1.118	
3	110	15	M		1 127	
4	117	16 5	M		1.155	
5	115	17 5	M		1 1511	
6	119	19 7	F		1 169	
7	128	22 9	M		1 092	
8	119	19	F		1.127	
9	135	29 5	F		1 199	
10	139	32 2	Md		1.199	
11	138	30 8	Md		1.172	
12	147	31.3	F		0 985	
13	141	31.1	Md		1 109	
14	156	37.8	M		0 996	
15	176	56 9	Md		1 044	
Ave.	132	26 71			1 118	
SD	18	10.9			0 06d	
SE	5	2 8			0 017	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/29/89	Group II	Rwy 42	temp=4			
1	116	16 9	Md	32	1 083	
2	127	22.9	M	31	1.118	
3	116	17.1	M	28	1.096	
4	132	25 3	F	33	1.1	
5	116	17.2	M	35	1.102	
6	125	22.6	F	38	1.157	
7	134	29.6	Md	39	1.23	
8	123	20.5	F	33	1.102	
9	122	20 8	F	36	1.145	
10	124	23	M	37	1.206	
11	119	19.4	M	33	1 151	
12	116	17.5	M	41	1 121	
13	159	46 2	F	36	1 149	
14	151	36.4	F	37	1 057	
15	115	16 5	F	37	1 085	
Ave	126	23.5		35	1 127	
SD	13	8 3		3	0 047	
SE	3	2 1		1	0 012	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/29/89	Group III	Rwy 42	temp=4			
1	125	21 4	M		1.09-d	
2	121	20 3	F		1.146	
3	129	24.4	F		1.137	
4	149	36 8	M		1.112	
5	113	17 8	F		1 234	
6	114	16.7	M		1 127	
7	121	21	F		1.185	
8	136	26.8	Md		1 065	
9	124	21.4	Md		1 122	
10	110	16 6	M		1 247	
11	127	22 3	F		1 089	
12	107	12.7	F		1 037	
13	133	27	F		1.148	
14	111	15	M		1.097	
15	170	52.8	Md		1.075	
Ave	126	23 5			1.128	
SD	17	10			0 059	
SE	4	2 6			0 015	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 29 89	Group IV	Rwy 42	temp=4			
1	108	12 6	M		1	
2	143	31 6	Md		1 081	
3	117	16	F		0 999	
4	138	23 9	F		0 909	
5	115	16 3	F		1 072	
6	128	21 8	Md		1 04	
7	112	14 6	M		1 039	
8	128	22 1	Md		1 054	
9	116	15 3	F		0 98	
10	109	13 2	F		1 019	
11	107	12 9	M		1 053	
12	124	21 9	Md		1 149	
13	116	16 6	M		1 063	
14	115	14 1	M		0 927	
15	132	23 2	F		1 009	
16	104	11 8	F		1 049	
17	119	17	M		1 009	
18	161	40 6	Md		0 973	
19	116	14 7	F		0 942	
20	127	20 3	F		0 991	
Ave	122	19			1 018	
SD	14	7 1			0 057	
SE	3	1 6			0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 29 '89	Group I	Rwy 43	4 20pm	temp=4		
1	111	15 4	M		1 126	
2	113	15 6	M		1 081	
3	109	14 5	F		1 12	
4	115	17 7	F		1 164	
5	115	17 6	M		1 157	
6	113	15 6	Md		1 081	
7	119	19	Md		1 127	
8	106	14	F		1 175	
9	119	17 5	M		1 038	
10	110	16 6	F		1 247	
11	119	20 1	F		1 193	
12	125	22 2	M		1 137	
13	124	21 7	M		1 138	
14	122	20 5	M		1 129	
15	152	38	M		1 082	
Ave	118	19 1			1 133	
SD	11	5 8			0 052	
SE	3	1 5			0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 29 89	Group II	Rwy 43	temp=4			
1	107	13 2	F	30	1 078	
2	100	11 3	Md	31	1 13	
3	115	17 2	F	34	1 131	
4	111	14 5	F	39	1 06	
5	107	15 2	Mp	35	1 241	
6	114	17 6	M	38	1 188	
7	112	14 7	M	39	1 046	
8	135	25 4	F	38	1 032	
9	132	27 4	F	38	1 191	
10	118	17 7	F	39	1 077	
11	117	17 7	F	38	1 105	
12	113	15 2	M	37	1 053	
13	145	31 9	F	40	1 046	
14	149	35 7	Md	37	1 079	
15	160	48 9	F	42	1 194	
Ave	122	21 6		37	1 11	
SD	18	10 4		8	0 066	
SE	5	2 7		1	0 017	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 29 89	Group III	Rwy 43	temp=4			
1	115	17 7	M		1 164	
2	116	16 5	F		1 057	
3	106	14 4	Md		1 209	
4	110	16	Md		1 202	
5	110	15 2	F		1 142	
6	118	18 7	Md		1 138	
7	134	25 2	M		1 047	
8	101	11 5	M		1 116	
9	119	19 9	M		1 181	
10	121	19 9	M		1 123	
11	119	20 1	Md		1 193	
12	125	22 8	M		1 167	
13	138	25 6	F		0 974	
14	134	28 4	M		1 18	
15	131	25	M		1 112	
Ave	120	19 8			1 134	
SD	11	4 8			0 065	
SE	3	1 2			0 017	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 29·89	Group IV	Rwy 43	temp=4			
1	139	24 5	Md		0 912	
2	110	14	M		1 052	
3	130	22	F		1 001	
4	108	12 4	M		0 984	
5	110	13 7	F		1 029	
6	117	16 6	F		1 036	
7	115	16 6	M		1 091	
8	115	18	M		1 184	
9	117	17 6	F		1 099	
10	113	14 6	F		1 012	
11	108	12 8	M		1 016	
12	115	14 5	F		0 953	
13	124	20 4	M		1 07	
14	149	33 7	F		1 019	
15	133	23 6	M		1 003	
16	126	21 3	M		1 065	
17	117	18 9	F		1 18	
18	168	48 6	M		1 025	
19	124	20 7	F		1 086	
20	130	22 1	F		1 006	
Ave	123	20 3			1 041	
SD	15	8 4			0 066	
SE	4	2 2			0 015	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3·30 89	Group I	Rwy 44	7 50 am	temp=4		
1	108	13 8	M		1 095	
2	119	19 1	M		1 133	
3	115	18 5	M		1 216	
4	109	14 6	M		1 127	
5	117	17 3	F		1 08	
6	118	17 3	M		1 053	
7	108	14 7	F		1 167	
8	110	14 5	F		1 089	
9	120	20	M		1 157	
10	121	21 9	F		1 236	
11	111	16 1	M		1 177	
12	140	33 6	Md		1 224	
13	132	26 7	M		1 161	
14	152	38 8	M		1 105	
15	155	42 3	F		1 136	
Ave	122	21 9			1.144	
SD	15	9 2			0 055	
SE	4	2 4			0 014	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 30/89	Group II	Rwy 44	temp=4			
1	104	7	F	32	0 622	
2	116	17 4	F	29	1 115	
3	112	16.1	M		1 146	
4	120	19	F		1 1	
5	116	18 2	M	37	1 166	
6	122	19 4	F	37	1 068	
7	119	18 8	F	35	1 116	
8	123	22 7	F	32	1 22	
9	119	19 7	F	35	1 169	
10	119	19 8	M	35	1 175	
11	131	25.6	M	34	1 139	
12	135	27 3	F	36	1 11	
13	121	20 1	F	35	1 135	
14	151	37 7	Md	28	1 095	
15	162	46 2	Md	32	1 087	
Ave	125	22 3		34	1 097	
SD	15	9 3		3	0 137	
SE	4	2 4		1	0 035	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/30/89	Group III	Rwy 44	temp=4			
1	114	16 4	F		1 107	
2	109	14 3	F		1 104	
3	113	17 6	M		1 22	
4	117	17 9	M		1 118	
5	115	17 7	F		1 164	
6	122	19 4	M		1 068	
7	122	20 9	F		1 151	
8	116	17	F		1 089	
9	124	22 3	F		1 17	
10	119	21	M		1 246	
11	122	21	M		1 156	
12	120	21 2	F		1 227	
13	114	18	F		1 2[illegible]5	
14	132	27.1	M		1 178	
15	140	32	Md		1 166	
Ave	120	20 3			1 159	
SD	8	4 5			0 054	
SE	2	1 1			0 014	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 30'89	Group IV	Rwy 44	temp=4			
1	116	16 9	F		1 083	Lm
2	132	24	M		1 043	
3	123	19 7	F		1 059	
4	118	15 9	M		0 968	
5	115	17	M		1 118	
6	125	19 3	F		0 988	
7	107	12 8	M		1 045	
8	119	16 7	F		0 991	
9	119	17 9	M		1 062	
10	111	14	M		1 024	
11	118	15 8	F		0 962	
12	116	15 7	M		1 006	
13	118	17 4	F		1 059	
14	130	23	M		1 047	
15	123	20 6	Md		1 107	
16	158	40 3	F		1 022	
17	111	13 9	M		1 016	
18	105	11 6	F		1 002	Dead
19	104	12	M		1 067	Dead
20	109	15 1	F		1 166	Dead
Ave	119	18			1 042	
SD	12	6 2			0 052	
SE	3	1 4			0 012	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/30/89	Group I	Rwy 45	10 00 am		temp=4	
1	115	17 4	M		1 144	
2	107	14 3	F		1 167	
3	107	13 7	F		1 118	
4	118	18 6	F		1 132	
5	122	21 3	M		1 173	
6	111	15 8	M		1 155	
7	120	20 7	F		1 198	
8	115	17 4	M		1 144	
9	119	19 2	F		1 139	
10	123	21 6	F		1 161	
11	124	21 9	F		1 149	
12	124	21 6	Md		1 133	
13	140	33 2	F		1 21	
14	153	40	F		1 117	
15	161	41 3	F		0 99	
Ave	124	22 5			1 142	
SD	16	8 7			0 05	
SE	4	2 2			0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3 30 89	Group II	Rwy 45	temp=4			
1	100	10 3	M	31	1 03	
2	116	17 1	F	30	1 096	
3	124	23 6	M	3[illegible]	1 238	
4	113	16 5	F		1 144	
5	109	15 8	F		1 22	
6	128	23	F	32	1 097	
7	116	16 3	M	35	1 044	
8	109	14 2	M	32	1 097	
9	110	14 9	Md	30	1 119	
10	115	16 6	M	37	1 091	
11	120	20 9	Md	38	1 209	
12	125	23 5	Md	37	1 203	
13	130	23 8	Md	32	1 083	
14	125	23 3	Md	35	1 193	Lm
15	132	24 8	M	37	1 078	
Ave	118	19		34	1 13	
SD	9	4 5		3	0 067	
SE	2	1 2		1	0 017	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/30/89	Group III	Rwy 45	temp=4			
1	98	10 4	F		1 105	
2	105	12 6	F		1 088	
3	142	33 1	Md		1 156	
4	113	18 1	F		1 254	
5	129	24 7	M		1 151	
6	110	14 4	F		1 082	
7	111	16 6	M		1 214	
8	126	23 5	Md		1 175	
9	122	21 9	F		1 206	
10	126	22 8	M		1.14	
11	114	16 4	F		1 107	
12	127	[illegible]7	Md		1 011	
13	133	[illegible]8	M		1 182	Lm
14	144	33	M		1 105	
15	143	34 5	M		1 18	
Ave	123	22			1 144	
SD	14	7 6			0 062	
SE	4	2			0 016	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/30·89	Group IV	Rwy 45	temp=4			
1	117	16 1	M		1 005	
2	115	16 3	F		1 072	
3	113	14 5	F		1 005	
4	106	11 9	F		0 999	
5	117	16 4	M		1 024	
6	123	18 3	F		0 983	
7	115	14 7	F		0 967	
8	115	15 1	M		0 993	
9	114	15 8	M		1 066	
10	115	15 4	M		1 013	
11	142	30 8	M		1 076	
12	141	30 9	F		1 102	
13	117	17 8	F		1 111	
14	118	16 4	F		0 998	
15	109	12 5	M		0 965	
16	115	16 1	F		1 059	
17	114	14 5	M		0 979	
18	147	34 1	Md		1 074	
19	158	39	F		0 989	
20	117	15 3	F		0 955	
Ave	121	19 1			1 022	
SD	14	7 8			0 048	
SE	3	1 7			0 011	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/12/89	Group I	Rwy 42	10 20 am		temp=6 5	
1	119	18 6	F		1 104	
2	117	18 6	F		1 161	
3	123	22 2	F		1 193	
4	124	22 9	F		1 201	
5	122	23	M		1 267	
6	121	20 2	Md		1 14	
7	118	18 2	M		1 108	
8	120	18 7	M		1 082	
9	117	18	F		1 124	
10	114	16 5	F		1 114	
11	114	16 5	F		1 114	
12	116	17 7	M		1 134	
13	126	23 6	M		1 18	
14	128	25 2	F		1 202	
15	175	59 1	M		1.103	
Ave	124	22 6			1 148	
SD	15	10 5			0 051	
SE	4	2 7			0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4·12·89	Group II	Rwy 42	temp=6 5			Subgrp#
1	123	21	F	26	1 129	1, Lm
2	122	20 5	M	36	1 129	1
3	129	24 8	Md	31	1 155	1
4	122	19 1	Md	30	1 052	1
5	159	43 8	Md	31	1 09	1
6	142	28 8	F	30	1 006	1
7	150	38	Md	38	1 126	1
8	162	49 8	Md	35	1 171	1
9	165	52 5	F	41	1 169	1
10	128	24	Md	27	1 144	2
11	120	18 8	F	32	1 088	2
12	117	16 9	F	29	1 055	2
13	121	19 4	M	36	1 095	2
14	121	20 9	M	55	1 18	2
15	126	24 1	F	39	1 205	2
Ave	134	28 2		34	1 12	
SD	17	12		7	0 055	
SE	4	3 1		2	0 014	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/12 89	Group III	Rwy 42	temp=6 5			
1	109	14 3	F		1 104	
2	148	37 6	M		1 16	
3	131	27 8	Md		1 237	
4	135	28 2	F		1 158	
5	138	28 5	F		1 084	
6	113	15 2	F		1 053	
7	129	25 8	Md		1 202	
8	115	17 3	M		1 138	
9	136	27 8	F		1 105	
10	123	20 8	F		1 118	
11	132	27 6	Md		1 2	
12	137	28 8	M		1 12	
13	127	22.6	F		1 103	
14	147	32 8	Md		1 033	
15	160	44 4	F		1 084	
Ave	132	26 6			1 127	
SD	14	8 1			0.057	
SE	4	2.1			0 015	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 12 89	Group IV	Rwy 42	temp=6 5			
1	111	12 7	M		0 929	
2	115	17	F		1 118	
3	115	18 7	F		1 23	
4	117	17	F		1 061	
5	113	15 1	F		1 047	
6	117	16 4	F		1 024	
7	108	12 1	F		0 961	
8	110	12.5	M		0 939	
9	132	22	M		0 957	
10	114	14 9	F		1 006	
11	130	23 9	Md		1 088	
12	123	19 3	M		1 037	
13	125	20 9	Md		1 07	
14	120	16 4	F		0 949	
15	163	47 4	Md		1 094	
16	112	14 2	M		1 011	
17	123	19 1	M		1 026	
18	154	36	M		0 986	
19	109	13 7	F		1 058	Dead
20	123	17 2	M		0 924	Dead
Ave	122	19 3			1 026	
SD	14	8 5			0 075	
SE	3	2 2			0 017	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/12/89	Group I	Rwy 43	1 30 pm		temp=6 5	
1	113	17	M		1 178	
2	115	17 3	M		1 138	
3	113	16 6	F		1 15	
4	110	15 3	M		1 15	
5	112	16 5	F		1 174	
6	103	12 4	M		1 135	
7	115	17	F		1 118	
8	103	12 8	M		1.171	
9	117	20 8	Md		1 299	
10	115	18 1	M		1 19	
11	116	17 1	M		1 096	
12	123	21 3	M		1 145	
13	133	26 9	Md		1 143	
14	125	22 4	M		1 147	
15	156	38 1	M		1 004	
Ave	118	19 3			1 149	
SD	13	6 4			0 061	
SE	3	1 6			0 016	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 12 89	Group II	Rwy 43	temp=6 5 subgrp #			
1	117	16 4	M	30	1 024	1
21	1141	16 5	M	36	1 114	1
3	115	17 8	M	38	1 17	1
4	108	14 7	F	38	1 167	1
5	112	15 6	M	39	1 11	1
6	109	14 4	M	34	1 112	1
7	118	17 5	Md	42	1065	1
8	125	20 8	M	40	1065	1
9	120	19 8	F	33	1 146	2
10	126	22 8	Md	37	1 14	2
11	120	19 2	M	34	1 111	2
12	124	22 1	F	38	1 159	2
1 31	140	30 1	F	33	1 097	2
14	158	4 0 2	M	33	1019	2
, 5	163	51				
Ave	1251	22 6	Md	36	1189 11131	2
SD	17	10 4		3	0 052	
SE	4	2 7		1	0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/12/89	Group III	Rwy 43	temp=6 5			
1	129	24 1	M		1 123	
2	132	28	M		1 217	
3	112	16 1	F		1 146	
4	120	19 4	M		1 123	
5	115	18 5	F		1 216	
6	111	16 5	Mo		1 206	
7	152	37 6	M		1 071	1
8	122	22 5	F		1239	
9	111	14 3	F		1046	
10	120	19 3	F		1117	
11	115	17 6	M		1157	
12	115	17 9	M		1 177	
13	143	32 7	F		1 118	
141	1391	31	F		1 154	
					1	
15	150	37 3	Md		1 148	
Ave	126	23 5				
SD	1a	7 9			0 056	
SE	4	2			0 014	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/12/89	Group IV	Rwy 43	temp=6 5			
1	105	12 2	M		1 054	
2	114	14 5	M		0 979	
3	153	35 4	M		0 988	
4	110	14	F		1 052	
5	120	19 1	M		1 105	
6	129	22 2	F		1 034	
7	114	14 8	M		0 999	
8	112	14 5	M		1 032	
10	130	211 0	M		0 1 oc-,	
		5	F		962	
11	107	1 2 4	M		1 012	
12	134	24 2	F		1 006	
13	110	13 6	M		1 022	
14	112	14 3	F		1 018	
15	112	14 2	F		1 011	
16	154	36 1	M		0 988	
17	112	14 2	F		1 011	
18	116	15 5	F		0.993	
19	119	1 6 13	M		0 997	
20	101	12.7	F			Dead
Ave	118	17 6			1.018	
SD	15	72)			0 032	
SE	3	1 6			0 007	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/13/89	Group I	Rwy 44	12 10 pm		temp=6 5	
1	115	17 7	F		1 164	
2	119	18	M		1068	
3	119	19 9	F		1 181	
4	127	22 3	F		1089	
5	117	18	M		1 124	
6	114	17 7	M		11951	
7	120	18 4	F		1 065	
8	114	15 6	F		1 053	
10	125	24 9	Md		1 275	1
11	130	25.1	M		1 142	
12	127	23 1	M		1 128	
13	130	24 2	M		1 102	
14	143	36.4	Md		1 245	
15	152	36.8	F		1.048	
Ave	125	22 4			1 135	
SD	11	6 5			0 068	
SE	3	1 7			0 018	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/13/89	Group II	Rwy 44	temp=6 5			subgrp #
1	109	16	M	30	1 235	1
2	122	20 2	F	31	1 112	1
3	132	26 3	F	31	1 143	1
4	113	16 4	M	36	1.137	1
5	140	28 7	F	33	1 046	1
6	144	33 1	M	36	1 109	1
7	134	26.5	M	42	1 101	1
8	142	34 6	F	43	1 208	1
9	171	57 2	F	40	1 144	1
10	116	17.1	F	31	1 096	2
11	120	19 4	M	36	1 123	2
12	120	19 5	M	32	1 128	2
13	140	30.3	M	32	1 104	2
14	159	43	Md	38	1 07	2
15	161	47.1	F	33	1 129	2
Ave	135	29		35	1 126	
SD	19	12 3		4	0 047	
SE	5	3 2		1	0 012	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/13/89	Group III	Rwy 44	temp=6 5			
1	119	19 4	F		1.151	
2	114	16 9	M		1 141	
3	147	35 7	Md		1 124	
4	120	21	M		1 215	
5	118	18 4	Md		1.12	
6	116	18 6	M		1 192	
7	118	18 2	F		1 108	
8	118	18	M		1 096	
9	113	16 5	F		1 144	
10	115	17.4	F		1 144	
11	120	19 3	M		1 117	
12	161	47.9	Md		1 148	
13	120	21	M		1 215	
14	124	22.1	F		1.159	
15	163	44.2	F		1 021	
Ave	126	23 6			1 14	
SD	17	10 2			0 049	
SE	4	2 6			0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/13/89	Group IV	Rwy 44	temp=6 5				4/13/89	Group I	Rwy 45	3:45 pm, Temp=6 5			
1	133	24 2	F		1 029		1	117	18 6	M		1 161	
2	106	12 2	F		1 024		2	115	18	M		1 184	
3	115	15	M		0 986		3	115	17 3	M		1 138	
4	122	17 9	M		0 986		4	111	15 6	M		1 141	
5	110	12.8	M		0 962		5	118	19 4	M		1.181	
6	120	1.9 4	F		1 123		6	112	16	F		1 139	
7	108	12 6	F		1		7	125	22 2	Md		1 137	
8	161	39	M		0 935	moribund	8	129	23 8	M		1 109	
9	110	13 1	M		0 984		9	124	24	F		1.259	
10	123	19 9	F		1 069		10	130	26 8	M		1 22	
11	109	13 9	M		1 073		11	120	21 6	M		1.25	
12	108	12 8	M		1 Old		12	120	22.2	Md		1.285	
13	112	13 7	M		0 975		13	12[illegible]	23 3	F		1.111	
14	156	35 6	F		0 938		14	124	22 8	M		1.196	
15	110	13						7	45.3	M		1.171	
16	127	19 3	M		00 999 967		Ave 15	123	22 5			1 179	
17	1091_	14 3	M		1 104		SD	11	7 1			0.0541	
18	123	18.7	M		1 005		SE	3	1 8			0 014	
19	109	13 4	F		1 035	Dead							
20	123	22 3	M		1 198	Dead							
Ave	120	18 2			1 02								
SD	15	7 5			0 066								
SE	3	1 7			0 015	.							
Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/13/89	Group II	Rwy 45	temp=6 5			subgrp #	4/13/89	Group III	Rwy 45	Temp=6 5			
1	115	18 2	M	35	1 197	1	1	120	19 9	F		1 152	
2	117	18 4	F	37	1 149	1	2	135	27 8	M		1 13	
3	126	20 8	M	33	1.04	1	3	114	17 9	F		1 208	
4	125	22 1	M	37	1 132	1	4	141	28 1	M		1 002	
5	118	20 5	F	38	1 248	1	5	109	15	M		1 158	
6	127	25 2	F	42	1.23	1	6	123	21	M		1 129	
7	138	30 5	F	38	1 161	1	7	119	18 7	F		1 11	
8	158	44 6	Md	46	1 131	1	8	114	16 6	F		1 12	
9	115	la 4	F	28	1.21	2	9	108	14 4	F		1 143	
10	111	15 3	M	37	1 119	2	10	128	23 9	F		1 14	
11	120	19 5	M	33	1 128	2	11	146	33	M		1 06	
12	123	20.4	M	40	1 096	2	12	116	17 6	M		1 128	
13	128	23.7	F	40	1.13	2	13	132	26.5	Md		1.152	
14	143	33.9	F	34	1.159	2	14	143	33	Md		1 129	
15	153	39 1	M	38	1 092	2	15	139	30 4	F		1 132	
Ave	128	24.7		37	1.148		Ave.	126	22 9			1.126	
SD	14	8.5		4	0.055		SD	13	6 5			0 046	
SE	4	2.2		1	0 014		SE	3	1 7			0 012	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 13 89	Group IV	Rwy 45	temp=6 5			
1	165	4 4	Md		0 979	
2	105	11 4	F		0 985	
3	115	15 8	F		1 039	
4	114	14 7	M		0 992	
5	116	16 1	M		1 031	
6	107	12 6	F		1 029	
7	126	20 4	M		1 02	
8	104	11 8	M		1 049	
9	148	33 1	Md		1 021	
10	117	16 2	F		1 011	
11	123	20	F		1 075	
12	119	16 8	Md		0 997	
13	117	16 4	Md		1 024	
14	119	17	M		1 009	
15	119	16 3	M		0 967	
16	114	14 7	M		0 992	
17	121	16 6	M		0 937	
18	116	16 3	F		1044	
19	93	8 4	F		1 044	Dead
20	112	14 3	F		1 018	Dead
Ave	114	17 61			1 013	
SD	15	7 8			0 032	
SE	3	1 8			0 007	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 14 89	Group II	Rwy 42 crowded				
1	110	15 1	M	30	1 134	
2	104	13 3	F	33	1 182	
3	115	17 4	M	35	1 144	
4	119	19 8	M	26	1 175	
5	118	18 6	M	36	1 132	
6	113	16	F	35	1 109	
7	130	24 9	F	32	1 133	
8	122	20 5	M	42	1 129	
9	112	17 8	F	40	1 267	
10	113	17	F	42	1 178	
11	120	17 2	M	36	0 995	
12	118	19 5	M	45	1 187	
13	125	20 8	M	40	1 065	
14	138	32 7	F	30	1 244	
15	169	51 8	M	36	1 073	
Ave	122	21 5		36	1 148	
SD	15	9 6		5	0 068	
SE	4	2 5		1	0 018	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 14 89	Group III	Rwy 42 crowded				
1	108	15 2	F		1 207	
2	146	36 7	M		1 179	
3	115	17 4	F		1 144	
4	123	20 1	F		1 08	
5	128	23 1	M		1 101	
6	116	17 4	F		1 115	
7	152	39 4	F		1 122	
8	119	18 9	M		1 122	
9	115	18 7	M		1 23	
10	117	17 4	M		1 086	
11	112	16 3	F		1 16	
12	130	25 8	F		1 174	
13	119	18 8	F		1 116	
14	123	19 2	F		1 032	
15	175	60 6	Md		1 131	
Ave	127	24 3			1 133	
SD	18	12 3			0 051	
SE	5	3 2			0 031	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 14 89	FL of other fish in sample rwy 42					
1	116	126	119			
2	120	112	136			
3	116	114	111			
4	140	131	126			
5	144	132	137			
6	114	121	127			
7	117	119	120			
8	127	119	128			
9	115	127	145			
10	133	118	121			
11	116	113	143			
12	123	121	127			
13	128	119	151			
14	121	114	134			
15	115	115	119			
16	129	119				
17	168	126				
18	127	125				
1 a	114	119				
20	116	118				
Ave	125					
SD	11					
SE	1					

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 14 89	Group II	Rwy 45 crowded				
1	113	16 3	F	36	1 13	
2	115	18 5	M	34	1 216	
3	117	18 4	M	29	1 149	
4	122	20 5	M	37	1 129	
[illegible]	[illegible]	3	M	36	1 28	
7	111	2(19 8	F	33	1146 1157	
[illegible]	[illegible]	[illegible] 7	F	33		
8	122	20 6	F	39	1 134	
9	109	15 7	F	38	1 212	
10	121	20 9	F	37	1 18	
11	121	20 1	M	40	1 135	
12	121	20 9	F	38	1 18	
13	130	25 3	F	41	1 152	
14	131	28 3	F	37	1 259	
15	167	59 2	F	40	1 271	
Ave	123	22 7		37	1 182	
SD	14	10 6		3	0 053	
SE	4	2 7		1	0 014	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/14 89	Group III	Rwy 45 crowded				
1	144	33 8	F		1 132	
2	118	20 8	F		1 266	
3	118	20 2	F		1 229	
4	112	16 6	F		1 182	
5	115	18	F		1 184	
6 7	1 118	22 19 5	F		1 187	
		? 9	M		1 172	
8	142	34 3	F		1 198	
9	120	21 2	F		1 227	
10	118	17 7	Md		1 077	
11	121	20 6	F		1 163	
12	118	18 8	M		1 144	
13	146	3 5	Md		1 125	
14	130	27 1	M		1 234	
15	123	22 8	F		1 225	
Ave	125	23 3			1 183	
SD	11	6 3			0 05	
SE	3	1 6			0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4 14 89	FL of other fish in sample rwy 45												
1	112	122	110										
2	119	149	109										
3	116	122	119										
4	141	131	134										
5	122	113	123										
6	122	112	143										
7	112	114	107										
8	119	124	142										
9	118	117	116										
10	121	112	1107										
11	123	118	119										
12	120	131	120										
13	122	122	116										
14	109	121	124										
15	114	116	113										
16	146	122	127										
17	126	129	121										
18	121	109	143										
19	130	115	115										
20	123	113	159										
Ave	123												
SD	11												
SE	1												

Warm Springs | Md=developing male; Mp=fully developed, precocious male; An=anemic

Lp=pale liver; Lm=mottled liver; T=coded wire tag; B=branded

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3/6/89	Group 1	Rwy 11	12 20 pm	temp=4 5		
1	127	21.7	M		1 059	
2	141	34 5	Md		1 231	
3	151	38 8	F		1 127	
4	133	26 7	F		1.135	
5	148	36.7	F		1.132	Lp
6	146	33.2	Md		1 067	
7	127	22 6	Md		1 103	
8	139	32.7	F		1 218	
9	114	16	F		1.08	
10	130	25.4	F		1 156	
11	125	2 1	Md		1 075	
12	114	15 7	F		1 06	
13	137	29.8	F		1.159	Lp
14	110	14.5	F		1 089	
15	139	28.7	F		1 069	
Ave	132	26.5			1 117	
SD	13	7 8			0 055	
SE	3	2			0 014	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3/6/89	Group II	Rwy 11,	temp=4 5			
1	127	22 9	M	37	1 118	
2	131	25 5	F	40	1 134	Lp
3	145	33 5	F	41	1 099	
4	117	16.8	M	44	1 049	
5	137	27	M	44	1 05	
6	157	45 4	Md	37	1.173	
7	144	35 3	F	40	1 182	
8	116	17 6	F	36	1 128	
9	138	29.1	M	42	1 107	
10	138	28 3	M	35	1 077	
11	124	22.7	M	39	1 191	
12	135	27 6	F	39	1 122	Lp
13	131	24 7	F	41	1 099	
14	115	17 4	F	40	1 144	
15	124	20 3	M	32	1 065	
Ave	132	26 3		39	1 116	
SD	12	7 7		3	0 045	
SE	3	2		1	0 012	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3/6/89	Group III	Rwy 11	temp=4 5			
1	143	36 7	F		1.255	
2	175	59 3	F		1 106	
3	146	35 9	F		1 154	
4	134	26 8	F		1 114	Lp
5	183	56 9	M		0 928	
6	114	17 1	F		1 154	
7	124	20 8	F		1 091	
8	146	37 4	F		1 202	
9	128	24 6	F		1 173	
10	124	21 2	F		1 112	
11	163	43 8	F		1 011	Lp
12	123	20 2	M		1 086	
13	126	23 6	F		1 18	
14	138	29 4	F		1.119	
15	140	32 1	F		1 17	Lp
Ave	140	32 4			1 124	
SD	20	12 9			0 081	
SE	5	3 3			0 021	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3/6/89	Group I	Rwy 13	3 40 pm,	temp=4 5		
1	159	41 1	F		1 022	
2	135	26 5	F		1 077	
3	145	31 2	M		1 023	
4	135	26 6	F		1 081	
5	136	25 1	M		0 998	
6	132	25 9	F		1 126	
7	133	27 3	M		1 16	
8	133	24 9	M		1 058	
9	142	32 5	F		1 135	
10	107	12 4	F		1 012	
11	137	27 6	F		1 073	
12	129	23 2	M		1 034	
13	134	26 2	F		1 089	Lp
14	113	15 6	F		1 081	
15	131	22	M		0.979	
Ave.	133	25 8			1 063	
SD	12	6.7			0 052	
SE	3	1 7			0 014	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3.6/89	Group II	Rwy 13	temp=4 5			
1	135	26	F	40	1 057	
2	138	27 7	[illegible]	49	1 054	
3	143	29 6	F	45	1 012	
4	122	18 6	M	40	1 024	
5	135	26 8	M	46	1 089	
6	127	23 3	F	45	1 137	
7	122	19 3	F	48	1 063	
8	114	16 6	F	41	1 12	
9	133	26 1	F	46	1 109	
10	125	22 5	M	51	1 152	
11	[illegible]	[illegible]7 7	F	[illegible]	[illegible]	
12	135	26.6	F	41	1 081	
13	122	17.7	Md	44	0 975	
14	120	18 2	F	47	1 053	
15						
Ave	126	21 9		45	1 061	
SD	12	5 9		4	0 062	
SE	3	1 6		1	0 0171	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3/6/89	Group II	Rwy 13,	temp=4 5			
1	116	16 9	M		1 083	
2	120	19 8	F		1 146	
3	117	19	F		1 186	
4	127	20 9	F		1 02	
5	129	22 3	F		1 039	
6	128	21 6	F		1 03	
7	125	22.9	M		1 172	
8	140	30	M		1 093	
9	140	32 3	Md		1 177	Lp
10	140	28 9	F		1 053	
11	142	32 4	M		1 132	
12	120	18 8	F		1 088	
13	125	21 3	F		1 091	
14	132	22 5	F		0 978	
15	123	20	M		1 075	
Ave	128	23 3			1 091	
SD	[illegible]2	5 [illegible]			0 062	
SE		131			0 0161	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3 21 89	Group I	Rwy 11	9 10 am temp=8			
1	124	19 9	F		1 044	
2	126	25	F		1 25	
3	135	26 4	F		1 073	
4	135	28	M		1 138	
5	139	29 2	F		1 087	
6	136	28 9	F		1 149	Lp
7	143	32 6	M		1 115	
8	136	28 9	Md		1 149	
9	125	21 9	F		1 121	
10	146	36 5	F		1 173	
11	147	35 4	F		1 114	
12	146	34 1	M		1 096	
13	160	46 5	F		1 135	
14	148	38 2	F		1 178	
15						
Ave	139	30 8			1 13	
SD	10	7			0 051	
SE	3	1 9			0 014	

Fish #	FL (mr	Wt (g)	Sex	Hct	Cond	Other
3.21.89	Group II	Rwy 11	temp=8			subgrp #
1	134	25 9	F	29	1 076	1
2	130	23 2	F	31	1 056	1
3	133	27 1	M	25	1 152	1
4	124	21 8	M	29	1 143	1
5	135	26.3	M	32	1 069	1
6	142	30 3	Md	42	1 058	1 Lm Lp
7	136	26 3	M	31	1 046	1
8	135	27 3	M	36	1 11	2
9	130	26 9	F	32	1 224	2
10	130	24 3	M	26	1 106	2
11	137	27 9	F	39	1 085	2
12	140	33	F	31	1 203	2
13	131	25 1	F	32	1 117	2
14	141	31 9	F	39	1 138	2
15	146	35 6	F	37	1 144	2
Ave	135	27 5		33	1 115	
SD	6	3 7		5	0 053	
SE	1	1		1	0 014	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3.21.89	Group III	Rwy 11	temp=8			
1	121	20	F		1 129	Lm
2	128	24 1	M		1 149	
3	120	19 5	F		1 128	
4	137	29 6	F		1 151	
5	147	35 3	M		1 111	
6	132	26 1	F		1 135	
7	132	25 4	Md		1 104	
8	115	16 6	F		1 091	
9	138	29 2	F		1 111	
10	119	19 7	M		1 169	
11	[illegible]	17 6	F		1 071	
121	1291	24 5	F		1 146	
13	130	24 6	F		1 138	
14	131	25	F		1 112	
15	126	22 3	M		1 115	
Ave	128	24			1 124	
SD	9	5			0 025	
SE	2	1 2			0 007	

Fish #	FL (mr	Wt (g)	Sex	Hct	Cond	Other
3.21.89	Group I	Rwy 13 12 50 pm			temp=8	
1	121	20 8	M		1 174	
2	122	20 4	M		1 123	
3	130	25 2	F		1 147	
4	132	25 9	M		1 126	
5	131	25 9	Md		1 152	Lp
6	143	33 3	F		1 139	
7	141	31 1	M		1 109	
8	148	38 4	M		1 046	
9	137	26 9	F		1 046	
10	137	27 8	Md		1 081	
11	149	34 7	M		1 049	
12	160	43	F		1 05	
13	167	48 5	F		1 041	
14	190	75 5	Md		1 101	
15	184	62 9	Md		1 01	
Ave	146	36			1 093	
SD	21	15 8			0 05	
SE	5	4 1			0 013	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3.21/89	Group II	Rwy 13	temp=8			subgrp #
1	119	20 6	F	36	1 222	1
2	124	20 7	F	33	1 086	1
3	140	28.1	Md	35	1 024	1
4	117	17 7	F	34	1 105	1
5	130	25	M	39	1.138	1
6	140	30	F	38	1 093	1
7	137	29 6	M	40	1 151	1
8	143	31	F	31	1.06	1
9	149	38 2	M	41	1 155	1
10	113	14 8	F	32	1 026	2
11	125	20 7	M	33	1.123	2
12	127	23	M	31	1 123	2
13	133	24.5	F	37	1 041	2
14	144	33	F	33	1.105	2
15	143	33 5	M	38	1.146	2
Ave	132	26		35	1.107	
SD	11	6 6		3	0 054	
SE	3	1 7		1	0 0141	

Fish #	FL (mr	Wt (g)	Sex	Hct	Cond	Other
3.21/89	Group II	Rwy 13	temp=8			
1	126	22	F		1 1	
2	144	32 4	M		1 085	
3	128	22 1	F		1 054	
4	134	26 7	M		1 11	
5	125	21 6	F		1 106	
6	184	62 8	M		1 008	
7	137	26 1	F		1 015	
8	142	30 5	F		1 065	
9	119	17 6	F		1 044	
10	138	30	M		1 142	
11	129	22 8	M		1 062	Lp
12	153	37	Md		1.033	
13	123	19 9	F		1 069	
14	133	26 4	F		1 122	
15	119	18 7	M		1 11	
Ave	136	27 8			1 073	
SD	16	11 1			0 04	
I S	4	291			0 01	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/3/89	Group I	Rwy 11	11 10 am temp=6			
1	120	18 4	F		1 065	
2	123	21 4	F		1 15	
3	130	25 5	M		1 161	
4	123	19 1	F		1 026	
5	124	20 9	M		1 096	
6	133	25 6	M		1 088	
7	136	28 6	F		1 137	
8	138	28 6	M		1 088	
9	145	37	F		1 214	
10	140	33.1	M		1 206	
11	149	43 8	Mp		1 324	
12	153	38 6	F		1 078	
13	155	40 5	M		1 088	
14	169	52 4	M		1 086	
15	174	57 2	F		1 086	
Ave	141	32 7			1 126	
SD	17	12			0 075	
SE	4	3 1			0 019	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4 3 89	Group II	Rwy 11	11 10 am		temp=6	
1	139	30 6	F	32	1 139	
2	139	32 3	F	32	1 203	
3	132	25 5	F	33	1 109	
4	118	18 1	F	34	1 102	
5	137	29 9	M	29	1 163	
6	135	28 3	F	35	1 15	
7	148	36 5	F	48	1 126	
8	136	27 6	M	34	1 097	
9	135	27 8	F	4[illegible]	1 13	
10	149	35	M	33	1 058	
11	149	36 8	F	29	1 112	
12	138	29 2	M	38	1 111	
13	130	25 2	F	38	[illegible]	
14	137	29 4	M	37	1 143	
15	180	67 2	M	33	1 152	
Ave	140	32		35	1 13	
SD	14	10 8		5	0 034	
SE	3	3		1	0 009	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4 3/89	Group III	Rwy 11	temp=6			
1	153	44 1	Md		1231	
2	128	23 7	M		1.13	
3	144	36 5	Md		1 22	
4	118	19 5	F		1 187	
5	146	35 5	Md		1 141	
6	125	22 3	F		1 142	
7	150	39	M		1 156	
8	143	31 4	F		1074	
9	157	41 5	F		1072	
10	117	19 3	M		1205	
11	130	24 6	M		1 12	
12	135	27	M		1 097	
13	137	30	F		1 167	
14	136	27 7	F		1 101	
15	130	29 9	F		1138	
Ave	137	30 1			1 146	
SD	12	7 8			0 05	
SE	3	2			0 013	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4 3 89	Group IV	Rwy 11	temp=6			
1	143	28 3	M		0 968	
2	148	36 5	Md		1 126	
3	1[illegible]	2[illegible] 7	F		0 947	
4	137	25 7	F		0 999	
5	122	18 3	M		1 008	
6	136	25 1	F		0 998	
7	145	32 7	F		1 073	
8	125	21 6	M		1 106	
9	154	37 5	Md		1 027	
10	138	25 8	M		0 982	
11	165	47 2	Md		1 051	
12	150	34 7	F		1 028	
13	145	32 2	M		1 056	
14	125	20	F		1 024	
15	142	29 3	F		1 023	
16	150	34 9	M		1 034	
17	117	16 8	F		1 049	Dead
18	112	14 5	F		1 032	Dead
19	131	27 2	F		1 21	Dead
20	121	20 2	F		1 14	Dead
Ave	137	27 8			1 044	
SD	14	8 1			0 063	
SE	4	2 1			0 14	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4 3 89	Group I	Rwy 13	1 30 pm temp=6			
1	119	19 5	M		1 157	
2	118	16 4	M		0 998	
3	132	24 9	M		1 083	
4	120	18 4	M		1 065	
5	133	27 7	F		1 177	
6	136	30	F		1 193	
7	143	33 5	M		1 146	
8	142	33	M		1 153	
9	149	34 5	M		1 043	
10	164	47 4	F		1 075	
11	148	36 1	M		1 114	
12	145	32 8	[illegible]		1 076	
13	157	42 3	M		1043	
14	182	71 9	Md		1 193	
15	182	63	F		1 045	
Ave	145	35 4			1 107	
SD	20	15 6			0 06	
SE	5	4			0 015	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4 3 89	Group II	Rwy 13	temp=6			
1	131	24 1	F	29	1 072	
2	125	23 5	F	36	1 203	
3	134	26 9	F	39	1 118	
4	136	30	M	34	1 193	
5	135	29	F	36	1 179	
6	122	22	F	30	1 212	
7	139	31 3	M	35	1 165	
8	141	32 2	F	39	1 149	cloudy pl
9	145	32 5	M	31	1 066	
10	158	40 1	M	39	1 017	
11	157	45	F	37	1 163	cloudy pl
12	132	26 1	F	40	1 135	
13	133	28 7	F	34	1 22	
14	135	26 1	F	[illegible]	1 061	
15	156	39 4	F	41	1 038	
Ave	139	30 5		36	1 133	
SD	11	6 6		4	0 067	
SE	3	1 7		1	0 017	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/3/89	Group III	Rwy 13	temp=6			
1	140	30 3	M		1 104	
2	155	40.3	M		1 082	
3	150	42.4	Md		1 256	
4	138	30.5	F		1 161	
5	142	34.7	Md		1.212	
6	174	56	F		1.063	
7	149	36 4	M		1 1	
8	133	28 1	F		1.194	
9	138	31 4	F		1 195	
10	133	26	M		1 105	
11	138	28.9	F		1.1	
12	145	33.6	Md		1.102	
13	150	36.5	F		1.081	
14	131	26 6	Md		1.183	
15	140	30.6	F		1.115	
Ave.	144	34 1			1.137	
SD	11	7.7			0.058	
SE	3	2			0 015	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/3/89	Group IV	Rwy 13;	temp=6			
1	130	20.4	M		0 929	
2	130	22.5	F		1.024	
3	157	38 7	Md		1	
4	138	25 5	M		0.97	
5	150	32 6	F		0.966	
6	152	33.9	Md		0 965	
7	107	12 5	F		1.02	
8	134	23.2	F		0.964	
9	136	24 9	M		0 99	
10	135	22.7	M		0.923	
11	134	24 2	F		1.006	
12	125	19.6	F		1 004	
13	132	22.5	F		0.978	
14	124	19.2	M		1.007	
15	130	20 7	M		0.942	
16	148	31.9	F		0 984	
17	128	20 9	M		0 997	
18	135	26 3	F		1 069	Dead
		) 2	F		1.14	Dead
20 19	121 161	20 7	F		1.023	Dead
Ave	135	25 3			0.995	
SD	13	7 3			0.049	
SE	3	1 6			0.011	

Willamette | **Md=developing male; Mp=fully** developed, precoclour **male; An=anemic**

Lp=pale liver; Lm=mottled liver; T=coded wire tag; B=branded

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3 20/89	Group 1	Rwy 21A (April rel			11 30 am temp=4	
1	136	28 5	F		1 133	
2	135	42 1	F		1 131	
3	121	1 9	F		1 073	
4	140	3 0	M		1 093	
5	139	28 6	M		1 065	
6	133	28 4	F		1 207	
7	135	27 5	F		1 118	
8	154	40 6	F		1 112	
9	151	40 5	Md		1 176	
10	155	40 4	Md		1 085	
11	159	48 2	Md		1 199	
12	158	45 4	F		1 151	
13	153	38 5	F		1 075	
14	173	6 3	Md		1 217	
15	180	64 7	F		1.109	
Ave	149	39			1 13	
SD	16	12 9			0 051	
SE	4	3 3			0 013	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
3/20/89	Group II	Rwy 21A (April rel)			temp=4	Subgroup
1	118	17 2	M	33	1 047	1
2	118	17 3	M	35	1.053	Lp, Lm 1
3	127	23	M	30	1.123	1
4	128	21 2	M	32	1 011	Lordosis?1
5	128	23	F	36	1 097	1
6	152	42	F	341	1.1961	1
7	145	34 8	M	39	1 141	1
8	168	49 9	F	25	1.052	1
9	180	61 2	F	34	1 049	1
10	118	18 9	F	30	1 15	2
11	132	25 4	F	31	1.104	2
12	167	51 4	M	29	1.104	2
13	131	26	F	33	1.157	2
14	148	35 3	M	32	1 089	2
15	200	87 2	F	31	1 09	2
Ave	144	35 6		32	1 098	
SD	25	19 8		3	0 05	
SE	6	5 1		1	0 013	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
3 20.89	Group III	Rwy 21A (April rel			temp=4	
1	133	25 2	M		1 092	
2	134	26 8	M		1 114	
3	163	45 4	F		1 048	
4	143	33 2	F		1 135	
5	1431	3 2	F		1 094	
6	180	65 4	F		1 121	
7	132	24 7	M		1 074	
8	183	66 7	M		1 088	
9	136	27 9	F		1 109	
10	140	30 8	F		1 122	
11	133	27 1	F		1 152	
12	176	59 9	M		1 099	
13	135	27 9	F		1 134	
14	142	29 6	F		1 034	
15	185	70 3	M		1 11	
Ave	151	39 6			1 102	
SD	21	17 1			0 032	
SE	5	4 4			0 008	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/5/89	Group I	Rwy 21A (April rel)			9 00 am temp=8	
1	127	22 [illegible]	M		1.108	
2	136	29 1	F		1 157	
3	148	35 7	M		1 101	
4	140	29 1	F		1 06	
5	136	27	F		1 073	
6	142	31 8	F		1 111	
7	142	29 3	F		1 023	
8	146	33 8	F		1 086	
9	146	32 9	M		1 057	
10	150	37 3	M		1 105	
11	150	36 5	F		1 081	
12	173	60 6	M		1 17	
13	170	54 3	Md		1 105	
14	199	90 4	M		1 147	
15	192	82	F		1 159	
Ave.	153	42 2			1.103	
SD	21	20.5			0 042	
SE	5	5 3			0.011	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4·5/89	Group II	Rwy 21A (April rel			temp=8	
1	148	35 3	F	32	1 089	
2	131	24 5		28	1 09	
3	161	46 7	M	31	1 119	
4	134	25 6	M	30	1 064	
5	155	42 8	F	39	1 149	
6	166	48 6	F	35	1 062	
7	142	30 5	F	36	1 065	
8	156	43	M	38	1.133	
9	155	41 5	F	37	1.114	
10	147	35 4	F	36	1 114	
11	188	75 2	M	40	1 132	
12	187	73 4	F	41	1 122	
13	187	74 8	F	32	1.144	
14	154	40 1	M	25	1 098	Lct>2
15	151	36 9	M	31	1 072	
Ave	157	45		34	1105	
SD	18	16 7		5	0 03	
SE	5	4 3		1	0 008	

Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/5/89	Group III	Rwy 21A (April rel)			temp=8	
1	185	67	F		1.058	
2	152	34	M		0 968	
3	158	47 6	F		1 207	
4	159	47 3	Md		1 177	
5	134	27 9	F		1 16	
6	159	45.3	F		1 127	Lm
7	146	35 3	F		1 134	
8	160	45 1	Md		1.101	
9	140	29.4	M		1 071	
10	117	17 3	F		1.08	
11	132	27.1	F		1.178	
12	154	39.9	F		1.092	
13	177	56 9	M		1 026	
14	163	48 5	M		1 12	
15	138	27 8	F		1 058	
Ave	152	39 8			1.104	
SD	18	13 1			0 064	
SE	5	3 4			0 016	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/5/89	Group IV	Rwy 21A (April rel.			temp=8	
1	169	55 1	M		1 142	
2	144	30 3	F		1 105	
3	175	58.4	M		1 09	
4	144	29 7	F		0 995	
5	158	39 2	F		0 994	
6	162	42.1	F		0.99	
7	121	16.9	M		0 954	
8	180	60	F		1 029	
9	153	36 5	F		10191	
10	148	34	Md		1.049	
11	163	46 7	F		1.0781	
12	155	38 7	M		1.039	
13	159	40.2	M		1	
14	154	38 4	F		1.051	
15	155	37 7	M		1 012	
16	140	27 6	F		1.006	
17	144	30 4	M		1.018	
18	153	36 4	M		1.016	
19	153	39 4	Md		1 1	
20	132	22.2	F		0.965	
Ave.	153	38			1 028	
SD	14	11			0 046	
SE	3	2 5			0 01	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/5/89	Group I	Rwy 21B (May rel)			11.20 am temp=8	
1	121	18	F		1.016	
2	130	21 9	F		0.997	
3	145	34 1	F		1.119	
4	139	28 4	F		1.057	
5	138	28.6	M		1 081	
6	147	36.9	M		1 162	
7	145	34.5	M		1.132	
8	133	27.9	F		1.186	
9	156	43 8	F		1.154	
10	150	36 1	F		1.07	
11	142	31 9	F		1 114	
12	158	41.7	F		1.057	
13	156	45 8	F		1.206	
14	171	56.8	M		1.136	
15	186	73.8	Md		1 147	
Ave.	148	37.3			1 109	
SD	16	14			0 061	
SE	4	3 6			0 016	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/5/89	Group II	Rwy 21B (May rel)			temp=8	
1	135	25.1	F	29	1.02	subgrp 1
2	136	28.5	M	30	1.133	1
3	127	21 9	M	33	1.069	1
4	140	29.2	M	33	1.064	1
5	135	29.1	F	35	1.183	1
6	137	28.2	M	37	1 097	1
7	126	23.1	M	33	1.155	1
8	143	30.4	M	38	1 04	1
9	161	47.5	Mp	33	1.1381	1
10	163	46.3	M	341	1 0691	1
11	183	70.9	M	24	1 157	2
12	197	84.5	F	32	1 105	2
13	167	53	M	35	1 138	2
14	172	53 9	F	32	1 059	2
15	147	34 9	M	28	1 099	2
Ave	151	40 4		32	1.1021	
SD	21	1861		4	0.0481	
SE	[illegible]	4.8		[illegible]	[illegible] 012	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/5/89	Group III	Rwy 21B (May rel)			temp=8	
1	146	35 2	F		1.131	
2	149	35	M		1.058	
3	147	37.1	M		1.168	
4	138	27.7	F		1.054	
5	146	32.3	M		1.038	
6	157	40.8	F		1.054	
7	141	30	F		1 07	Lm
8	174	55 8	F		1.059	
9	1211	19.5	M		1.101	
10	165	50 7	Md		1.129	
11	129	24 1	F		1.123	
12	168	55 9	F		1.179	
13	161	46 8	M		1 121	
14	166	54 1	Md		1 183	
15	145	33 2	F		1.089	1 eye
Ave.	150	38.5			1.104	
SD	15	11.7			0.048	
SE	4	3			0.013	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/5/89	Group IV	Rwy 21B (May rel)			temp=8	
1	175	54.5	Md		1.017	
2	173	52 1	F		1 006	
3	128	20 7	M		0 987	
4	135	27.1	M		1 101	
5	166	44 2	M		0 966	
6	140	29 3	F		1 068	
7	143	27 9	M		0 954	
8	133	25.4	M		1.08	
9	182	61.9	M		1 027	
10	138	27.3	F		1 039	
11	132	26.7	F		1.161	
12	177	56.1	F		1 012	
13	182	63 4	M		1.052	
14	130	22	M		1 001	
15	145	30.6	F		1.004	
16	149	31.1	M		0 94	
17	158	39 4	F		0 999	
18	144	33	M		1 105	
19	155	38 6	F		1 037	
20	161	47 7	M		1 143	
Ave	152	38			1 035	
SD	18	13 6			0 06	
SE	4	3			0 013	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other
4/19/89	Group I	Rwy 21B (May rel)			1:00pm	
1	148	34.4	M		1.061	
2	132	28.6	M		1.243	
3	135	29	M		1.179	
4	149	36 1	M		1.091	
5	136	27 2	F		1.081	
6	153	39 4	F		1 1	
7	163	45 6	F		1.053	
8	140	30.8	F		1.122	
9	146	35 8	M		1 15	
10	158	46 9	F		1.189	
11	178	63	Md		1 117	
12	180	66 4	M		1 139	
13	166	49 7	M		1 087	
14	179	64 3	F		1 121	
15	205	96	M		1 114	
Ave.	158	46 2			1 123	
SD	21	19.1			0 051	
SE	5	4 9			0 013	

Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
4/19/89	Group II	Rwy 21B (May rel)					4/19/89	Group III	Rwy 21B (May rel.)				
1	140	29.3	F		1 068	subgrp 1	1	148	34.7	F		1.07	
2	136	28.3	F	36	1 125	1	2	151	38 9	F		1.13	
3	144	32.6	F	28	1.092	1	3	159	45	M		1.119	
4	165	50.7	F	43	1 129	1	4	171	60	F		1 2	
5	163	46.7	F	42	1 078	1	5	199	91 5	F		1.161	
6	194	81.9	M	36	1 122	1	6	137	29 8	F		1.159	
7	188	79.3	F	40	1 193	1	7	191	84.5	M		1.213	
8	142	33	M	32	1 153	2	8	162	47	F		1.105	
9	145	35.2	M	30	1 155	2	9	190	78.6	F		1.146	
10	163	47.7	M	36	1 101	2	10	152	39.8	F		1 133	
11	163	49 2	F	41	1 136	2	11	140	28 8	F		1.05	
12	165	50.2	F	37	1 118	2	12	158	47.1	F		1.194	
13	159	45.2	M	45	1.124	2	13	148	36.7	F		1.132	
14	187	73	F	38	1 116	2	14	189	81	Md		1 2	
15	197	92.3	M	34	1 207	2	15	175	70 8	Md		1.321	
Ave	163	51.6		37	1 128		Ave	164	54 3			1.156	
SD	20	20.5		5	0 038		SD	201	21.5			0.066	
SE	5	5.3		1	0 01		SE	5	5 6			0.017	
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
5/4/89	Group I	Rwy 21B (May rel)			10 20 am temp=10		5/4/89	Group II	Rwy 21B (May rel)			temp=10	
1	144	32.3	F		1 082		1	147	33 5	M	42	1.055	subgrp 1
2	145	32.4	M		1 063		2	[illegible]	39.5	M	38	1.061	1
3	141	30 2	F		1 077		3	[illegible]	41.9	F	47	1.083	1
4	163	44 9	M		1 037		4	150	36.9	M	41	1 093	1
5	147	33.5	F		1 055		5	151	35 2	M	38	1.022	1
6	157	40 4	M		1 044		6	146	33 8	F	38	1.086	1
7	140	30 2	F		1.101		7	148	33.5	F	42	1.033	1
8	145	33.3	F		1.092		8	190	76.5	F	37	1.115	2
9	165	46 9	F		1 044		9	152	38.1	F	38	1 085	2
10	157	43 6	F		1.127		10	192	77.1	M	41	1.089	2
11	171	49.7	F		0 994		11	195	83	M	42	1.119	2
12	155	39.6	M		1 063		12	154	39 8	M	39	1.09	2
13	185	66.9	F		1 057		13	170	53	F	40	1 079	2
14	192	84.4	M		1.192		14	174	64.8	Md	45	1 23	2
15	212	101.5	M		1 065		15	170	50	M	40	1 018	2
Ave.	161	47.3			1 073		Ave.	163	49 1		41	1.084	
SD	21	21.1			0 045		SD	17	17.4		3	0.051	
SE	5	5 5			0 012		SE	4	4.6		1	0.013	
Fish #	FL (mm	Wt (g)	Sex	Hct	Cond	Other	Fish #	FL (mm	Wt (g	Sex	Hct	Cond	Other
5/4/89	Group III	Rwy 21B (May rel)			temp=10		5/4/89	Group IV	Rwy 21B (May rel.)			temp=10	
1	159	40	M		0 995		1	159	39	F		0.97	
2	140	29.6	F		1 079		2	169	48	M		0.994	
3	210	111	Md		1 199		3	195	82.3	M		1.11	
4	162	45 8	F		1 077		4	170	50 1	F		1.02	
5	190	70 8	M		1 032		5	130	23 1	F		1.051	
6	153	34.4	F		0 96		6	148	34.2	F		1.055	
7	163	51 4	M		1 187		7	146	30.2	F		0.97	
8	160	40	M		0 977		8	142	29.2	F		1.02	
9	159	41.6	F		1 035		9	174	54	M		1.025	
10	165	48	M		1 069		10	147	29.5	M		0 929	
11	160	44.2	F		1.079		11	167	44.6	F		0.958	
12	170	51.6	M		1 05		12	164	39.7	M		0 9	
13	171	61.8	Md		1 236		13	146	31	F		0.996	
14	154	35	F		0 958		14	139	28	M		1.043	
15	182	66 8	F		1 108		15	158	41.4	F		1.05	
Ave	167	51 5			1 069		16	158	39 1	M		0.991	
SD	17	20 3			0 085		17	157	42.5	M		1.098	
SE	4	5 2			0 022		18	162	45 5	F		1 07	
							19	195	76 9	M		1 037	
							20	139	26 3	F		0 979	
							Ave	158	41 7			1.013	
							SD	17	15 5			0 054	
							SE	4	3 5			0 012	

APPENDIX 2

Hatchery Information

DWORSHAK NATIONAL FISH HATCHERY

Adult Spawners

Adult spring chinook salmon spawners (originally Rapid River stock, but also some Leavenworth, Little White Salmon, and Kooskia stocks) arrived at the hatchery from 22 May to 10 September 1987. Adults were held in adult holding ponds (17 x 75 ft, 7,500 cu ft water) with the upper one third shaded by a tarp and the remainder of the pond sprinkled to reduce stress. Inflowing water (1,645-2,110 gpm) was received from the North Fork of the Cleat-water and averaged IO-13° C (50-55° F). From a total of 2,017 adults (60% females, 40% males), 99 males and 220 females suffered prespawning mortality (15.8%). Numbers and age classes included 1 -ocean, 25: 2-ocean, 1,604; and 3-ocean, 376. While held, adults received malachite green treatments (1 mg/L for 1 hour) daily (Monday through Friday) from 28 May to 17 August. Spawning (1,591 fish) was conducted from 24 August to 8 September 1987, using MS-222 (100 mg/L) buffered with sodium bicarbonate as an anesthetic.

There were six egg takes, numbered 1 through 6, taken on 24, 25, 27, and 31 August, and on 3 and 6 September, respectively (total eggs = 3,3 16,340). Whenever possible, one male was used to fertilize the eggs from a single female. However, because of the sex ratio, males were often used twice. Tissue samples from males (kidney and spleen) and ovarian fluid from females were screened for IHN, BKD, VEN, Myxobolus, etc. A total of 5.6% (2.8% males and 7.7% females) tested IHN positive. Less than 1% were grossly infected with BKD.

Eggs

Green eggs were placed in Heath trays (eggs from two females. 7,000-7,500/tray) and water hardened for 30 minutes in 75 mg/L iodophore buffered with sodium bicarbonate. Eggs were incubated in ambient water (10-13° C/50-55° F), with those from IHN-(7.7%)

and BKD-positive parents kept separate from the rest. At eye-up (92.95 %), eggs were shocked, salted, picked, and counted. Hatching was completed by mid-October.

Early Rearing

Fry were transferred from incubation (Heath) trays to inside nursery tanks during 9-27 November. Each tank (100 cu ft) received untreated river water (35-50 gpm) that averaged from 8.80 C (47.80 F) in November to a low of 4.20 C (39.50 F) in January and February, and 6.8° C (44.3° F) in April when the fish were transferred to outside raceways. Generally, fry from three Heath trays were placed in each tank (19,000-30,000 fish). Just prior to transfer outside (first part of April), fry averaged 247/lb (195-306/lb) and 61 mm (2.4 in) in length (57-64 mm, 2.2-2.5 in). Fry from egg takes 3 and 4, which were placed in the raceways monitored by this study (raceways 11, 12, 13. and 14), were from 210-245/lb.

Biodiet Starter #2 was used for initial feeding, which began shortly after transfer to the nursery in mid-November, and was fed until the fish reached 900/lb. From this size until they reached 400/lb, Biodiet Starter #3 was used. Oregon Moist Pellets (OMP, 1/16) were fed starting at 400/lb. Fish were fed by hand, eight times daily. No antibiotics were used during nursery rearing. Tanks were cleaned daily by removing stand pipes and drawing water down about 50%. Skylights in the roof provided some light during daytime, but the main lighting was from electric lights turned on at 7:30 a.m. and off at 4:00 p.m.

Raceway Rearing

In mid April, fish were transferred to standard 8 x 80 ft flow-through raceways (1,320 cu ft) with about 80,000/raceway. Water was from the North Fork of the Clear-water River, with inflow rates of 562-636 gpm. Fish were divided in July, reducing pond densities (see the following table). Water levels were lowered once each week while ponds were cleaned. In addition, ponds were occasionally flushed and end screens cleaned. Some fish in ponds 14-17 were tagged with coded wire tags and freeze branded in December 1988. Some fish in ponds 13 and 14 (pond 13 was monitored in this study) received tags with code 05-40-15 (67,920) and some were branded (22,210; RD7H-3) on 7 December 1988. Fish were fed OMP, size 1/16, from 400 to 150/lb; 3/32 from 150 to 40/lb; and 1/8 from 40/lb to release. Other information on rearing densities, feeding, and growth is found in the following table:

Averages for all production fish

Year & Month	Fish/ pond	Fish/lb	Wt (g)	Lbs fish/ pond	Fl (in)	Fl (mm)	Density Index*	Water temp. (°F/°C)	Feed rate (%wt/ day)	Food conver. (food/ % gain)	Mort. (%)
1988											
April	90.778	168.0	2.7	540	2.60	67	0.16	42/5.6			
May	8 1,900	116.0	3.9	706	2.90	72	0.19	45P.2	1.0	1.38	0.8
June	76.150	76.3	6.0	998	3.30	83	0.23	51/10.6	1.7	1.52	0.6
July	47.100	60.5	7.5	778	3.50	90	0.17	54/12.2	1.2	1.83	0.2
August	41,600	44.4	10.2	938	3.80	98	0.19	55/12.8	1.6	1.52	0.3
Sept.	39.500	33.9	13.4	1167	4.04	103	0.22	55/12.8	1.6	1.79	0.5
Oct.	37,500	26.8	16.9	1400	4.66	118	0.23	52/11.1	1.3	1.90	0.4
Nov.	37.450	23.3	19.5	1606	5.09	129	0.24	46P.8	0.9	2.11	0.2
Dec.	37,100	21.5	21.1	1724	5.23	133	0.25	40/4.4	0.6	2.41	0.2
1989											
January	37,000	19.6	23.2	1890	5.30	135	0.27	4014.4	0.5	1.61	0.2
Feb.	36,800	19.9	22.8	1851	5.28	134	0.27	3913.9	0.3		0.3

Averages for monitored ponds 11, 12, 13, and 14

Year & Month	Fish/ pond	Fish/lb	Wt (g)	Lbs fish/ pond	Fl (in)	Fl (mm)	Density Index*	Water temp. (°F/°C)	Feed rate (%wt/ day)	Food conver. (food/ % gain)	Mort. (%)
1988											
April	81,000										
May	80.100	112.8	4.0	710	2.90	73	0.19	45n.2	--		1.2
June	79,500	76.8	5.9	1036	3.30	83	0.24	51/10.6	--		0.7
July	43.400	62.4	7.3	697	3.50	89	0.15	54/12.2	--	--	0.2
August	43,200	44.5	10.2	977	3.90	98	0.19	55112.8	--		0.4
Sept.	42,900	36.8	12.3	1176	3.90	100	0.23	55/12.8	--		1.0
Oct.	42.750	27.3	16.6	1565	4.63	118	0.26	52/11.1	--		0.3
Nov.	42,700	23.9	19.0	1788	5.05	129	0.27	46t7.8	--		0.1
Dec. **	40,300	22.4	20.3	1800	5.16	131	0.26	40/4.4			0.1
1989											
January	40,200	21.3	21.3	1887	5.15	131	0.28	40/4.4	--		0.2
Feb.	38.800	20.6	22.0	1889	5.21	132	0.28	3913.9	--		0.3

$$* \text{ Density Index} = \frac{\text{Fish weight (lbs)}}{\text{Fish length (in) X Water vol.(ft}^3)}$$

**9,360 fish removed from pond 14

Release

Fish were released on 30 and 31 March 1989. The size of fish in pond 13 was determined by hatchery personnel on 22 March and found to be 18.97/lb (23.9 g). A length distribution analysis on this date produced the following results:

	Fork length (cm)	No. of fish
	10	4
	11	41
	12	35
	13	31
	14	9
	21	1
Mean	12.1	121

For the total number of fish released directly into the North Fork of the Clearwater River (1,252,923), about 3.5% indicated some signs of BKD (popeye). Fish averaged 18.3/lb (24.8 g) and were 5.43 inches (138 mm) in length.

Water Chemistry

The following is an example of measurements made on untreated North Fork river water:

Temperature (°F)	40.4
Dissolved oxygen (mg/L)	12.4
PH	7.5
Hardness (mg/L)	8
Chloride (mg/L)	< 3
Sodium (mg/L)	0
Potassium (mg/L)	0.5

LEAVENWORTH NATIONAL FISH HATCHERY

Adult Spawners

Adult spring chinook salmon spawners (Carson/Leavenworth stocks) arrived at the hatchery from 26 May to 30 June 1987. Adults were held in two ponds (50 x 150 ft) receiving water from wells and the Icicle River. Temperatures of the river water ranged from 8.9 to18.3° C (48-65° F) and of the well from 8.9 to 10° C (48-50° F). At no time was the temperature allowed above 10° C (50° F) while adults were present. Flow rates varied according to the number of adults present (about 1 gpm/fish) to a maximum of 2,342 gpm. From a total of 2,342 adults, 158 (7%) died before spawning. While held, adults were treated with malachite green (1 ppm) for 1 hour three times weekly from 24 June to 27 July. Each adult received two injections of erythromycin (0.4- 1.2 cc/fish, depending on size). Spawning was conducted from 10 August to 2 September. There were six egg takes, numbered l-6, taken on 10, 17, 19, 25, 26 August and 2 September, respectively. Takes l-3 used a 1:1 ratio female to male. For takes 4-6 the ratio was 2:1. Fish monitored in this study (raceways 42, 43, 44, and 45) were from egg take 4. Spleen tissue from males and ovarian fluid from females were examined for IHN.

Eggs

Fertilized eggs from each female were placed in a separate colander and were then immersed in iodophore (75 mg/L, buffered with sodium bicarbonate) for 30 minutes. Eggs were destroyed if either parent had gross BKD lesions. Well water was used for incubation, and average monthly temperatures were: September, 12° C (53° F); October, 8° C (46° F); November, 9° C (49° F); and December, 10° C (50° F). After incubation in individual colanders, the eyed eggs (93%) were shocked and transferred to metal screen trays (~3,000/tray) which were placed in troughs until hatching. The transfer to trays occurred from mid-October to the first part of November. Eggs were treated three times each week with 167 ppm formalin until hatching.

Early Rearing

Fry were transferred from 1 December to mid-December, at 1.1 / l b , to inside troughs (14 x 1.3 x 0.86 ft; 15.6 cu ft rearing space; 9,OOO/trough) and fiberglass tanks (14 x 3.1 x 2.1 ft; 91.0 cu ft rearing space; 33,OOO/tank). Well water was used as the primary water source with trough and tank inflows 10 and 15 gpm, respectively. The average temperature for December and January was 8.80 C (47.8O F). In mid- to late-February, fish (average size 425/lb) were moved to outside ponds. Fish in raceways 42-35 (monitored in this study) were transferred on 25 January and loaded at 96,OOO/raceway. Biodiet Starter #2 was used for initial feeding (beginning 7-21 December). Fry from egg take #4 were fed initially on 11 December. No antibiotics were fed during this period nor were there any treatments for diseases.

Raceway Rearing

Fish were transferred from inside uoughs and tanks to outside ponds during late January through late February. Fish monitored in this study were placed in flow-through raceways (76 x 8 x 2.5 ft; 1,520 cu ft rearing space). In addition to raceways, both small (3,876 cu ft) and large (13,572 cu ft) Foster-Lucas ponds were used in rearing the fish to release. Fish used in this study were 2.2 in (12 mm) in length when uansferred to raceways (about 99,OOO/raceway; Density Index 0. IO). Icicle River and wells were used as water sources with inflows averaging 3 12 gpm. Average temperatures are shown in the table below. There was some freezing of ponds in January and February.

Fish were fed Oregon Moist Pellets (l/32, 3/64, and l/16) and Biodiet Moist (3 mm). No antibiotics were fed. Fish in some of the Foster-Lucas ponds were treated for Ichthyophthirius multifillis with formalin (1 to 5,000), 1 hour/day on alternate days, for 2 weeks. However, treatment was unnecessary in the raceways. Fish were thinned in May 1988 to their final release numbers (see table below). Raceway 45 was used for monthly weight/length sampling during which water was lowered and fish crowded. Ponds were cleaned weekly in winter and 4 days/week in the summer by scrubbing the bottom surface with a brush while the water level was lowered.

In November 1988, 203,554 fish were coded-wire-tagged with the following codes: RW 42; 05-19-53; RW 43; 05-17-53; RW 44 &45; 05-19-54. Raceways 46 and 47 were branded: RW 46: LA-7C-1, & RD-76-1; RW 47: LA-7C-3

Other information on rearing densities, feeding, and growth is found in the following table:

Year & Month	Fish/ pond	Fish/lb	Wt (g)	Lbs fish/ pond	Fl (in)	Fl (mm)	Density Index*	Water temp. (°F/°C)	Feed rate (%wt/ day)	Food cower. (food/ 8 gain)	hlort. (%)
1987											
Dec.	9.000	674	0.67	13.4	1.79	55	0.48	48/8.8	1.0	0.62	0.40
1988											
January	9,000	396	1.15	22.8	2.15	63	1.46	48/8.8	1.0	1.07	0.30
Feb.	96,000	241	1.88	398	2.49	77	0.06	44/6.5	1.0	0.73	0.07
March	95.950	122	3.72	786	3.02	84	0.09	45/7.2	1.0	0.88	0.03
April	95,900	95	4.78	1,009	3.32	84	0.19	44/6.7	1.0	1.05	0.01
May	26,394	76	5.97	347	3.54	90	0.06	44/6.7	1.0	1.34	0
June	26,391	58	7.83	455	3.89	99	0.08	48/9.0	1.0	1.44	0.01
July	26,383	43	10.56	614	4.30	109	0.09	55112.6	1.0	1.52	0.01
August	26,371	33	13.76	799	4.17	106	0.13	5019.9	1.0	1.52	0.01
Sept.	26,354	27	16.81	976	4.08	104	0.18	46/7.9	1.0	1.82	0.06
Oct.	26,336	24	18.92	1,097	4.54	115	0.19	44/6.8	1.0	2.43	0.01
Nov.	25,136	25	18.16	1,005	4.79	122	0.17	36/2.1	0.4	-2.87	0.0'
Dec.	25,127	26	17.46	966	4.65	118	0.18	32/0.2	0.1	-0.5 1	0.04
1989											
January	25,122	25	18.16	1,005	4.65	118	0.18	34/0.9	0.2	18.73	0.0'
Feb.	25,122	25	18.16	1,005	4.72	120	0.18	34/1.1	0.2	0	0
March	24,996	22	20.64	1.136	4.94	126	0.19	35/1.8	0.4	0.95	0.50
April			--	--		132		39/3.9	--	1.12	--

$$* \text{ Density Index} = \frac{\text{Fish weight (lbs)}}{\text{Fish length (in) X Water vol.}(\text{ft}^3)}$$

Release

Fish were released on 19 April at 20/lb by opening the drain to the ponds which fed directly into Icicle River.

WARM SPRINGS NATIONAL FISH HATCHERY

Adult Spawners

Adult spring chinook salmon (Warm Springs/Deschutes stock) arrived at the hatchery between 29 April and 30 September 1987. The mid-portion of the run arrived in mid-May. Adults were held in two oval concrete ponds with sloping sides. Total volume of both ponds was 8,350 cu ft. Incoming water (about 400 gpm) was taken from the Warm Springs River, passed through a sand filter, subjected to ultraviolet radiation, and chilled when needed to keep the temperature at 9-10° C (48-50° F). Water was recirculated with about 50% fresh water added. All hatchery adults had been, as juveniles, either tagged with a coded-wire tag (adipose fin clip) or marked with another fin clip. As adults entered the holding ponds, both hatchery and wild fish were anesthetized with a mixture of quinaldine and MS-222, injected with erythromycin, and given a dip in a malachite green bath (I ppm). Wild fish (those with no marks) were then released to proceed upriver. All adults held at the hatchery received a second injection of erythromycin. In August, there was an outbreak of Ichthvonhthirius multifillis; fish were treated twice weekly with 167 ppm formalin until spawned. There were 235 prespawning mortalities, primarily due to I. multifiliis. Adults also received a malachite green bath three times each week. Samples of kidney and spleen were taken from males, and ovarian fluid from females, and examined for IHN. One male and 10 females were IHN positive. Eggs from these fish were kept separate from the others and the progeny were reared in a separate raceway. A total of 267 females and 197 males were spawmed between 2 I August and 23 Scptcmbcr. In nearly all instances, eggs from each female were fertilized with sperm from only one male. Eggs from eight females showing gross BKD signs were destroyed. Three males also were grossly BKD infected. Eggs were taken on 21 and 27 August, and on 2,8, 14, 18, and 23 September 1987; a total of 724,613 eggs were obtained.

Eggs

Fertilized eggs from each female were placed in individual incubation buckets, water hardened in iodophore (Argentyne, 75 ppm, 30 minutes) and incubated in troughs using treated river water. Water was chilled so the temperature would not exceed 12° C (52° F) until normal river temperatures dropped below that value (about 1 October). Temperatures then remained as ambient until initial feeding. At eye-up, eggs (691,750) were shocked in salt water, picked, and moved to Heath trays. There was a 4.5% loss to the eyed stage. Eggs received no other chemical treatment during incubation. Hatching occurred in mid-November.

Early Rearing

In late December, fry were transferred from Heath trays to inside fiberglass tanks, with 40,000 to 50,000 fish per tank (3 x 13 x 2-ft deep; water volume = 78 cu ft). Treated river water was used with an inflow of 15 gpm and temperatures 8-10° C (46-50° F). First feeding was 25 December with Biomoist Starter II, later Biomoist Starter III. No antibiotics were fed during early rearing and there were no other treatments. Fish were fed initially every 1/2 hour, later every hour just before ponding.

Raceway Rearing

Fish were transferred to outside raceways beginning 16 March 1988. Raceways were modified Burrow's ponds with the center divider closed at the inlet end but open at the outlet end. The ponds were 16 x 75 x 1.54-ft deep (3,712 cu ft), with the center divider open at the tail end of the raceway, allowing fish free access to both sides. Approximately 52,000 fish were placed in each raceway. Untreated river water was the source with inflows at 500 gpm in winter and 700 gpm in summer. Fish were fed Biomoist diet (by hand, four to five times daily) in graded sizes up to 3 mm prior to release. Ponds were cleaned weekly in the summer and one or two times each month in winter. During the first part of July 1988, it was recommended that the fish be treated for 4 days with formalin (200 ppm) because of a high incidence of I. multifillis. In November 1988, the incidence of Nanophyetus was observed to be high (60-70 metacercarial cysts in the posterior kidney).

Fish were coded-wire-tagged or fin clipped between 7 April and 4 May 1988 (90-180/lb) and apportioned to about 52,000/raceway. In late September 1988, fish were graded, and those 140 mm and longer were released. The remaining, smaller fish (those used in this study) were kept in raceways with the following numbers (count at release 5 April 1989):

Racewav number	Number of fish	Wire tag&
11	30,253	05-20-05
12	34,996	05-20-07
13	62,788*	05-20-06 & 05-20-08

*28,165 originally in pond 13 plus 34,623 from pond 13.

These fish were then fed oxytetracycline to provide a mark to distinguish them from the larger fish that were released carrying the same wire-tag code.

Information on rearing densities, growth, temperatures, and food conversions are found in the following table:

Year & Month	Fish/ pond	Fish/lb	Wt (g)	Lbs fish/ pond	Fl (in)	Water temp. (°F/°C)	Food cower. (food/ % gain)	Mort. (%)
1987								
De-c.	69 1,750	532	0.9	–	1.37 (Est)	–		
1988								
January	–		–	–	–	–		
Feb.				–	–			
March	69 1,750	190	2.4	–	–	4115.0		
April	69 1,750	105	4.3	–	–	47/8.3	0.9	0.1
May	626,857	53.0	8.6	–	–	5 1110.6	1.1	0.1
June	626,352	29.0	15.7	–	–	57113.9	1.1	0.4
July	623,835	21.1	21.6	–	–	61116.1	1.6	0.1
August	623.038	18.4	25.2	–	–	59115.0	2.4	0.1
Sept. *	4 16,887	18.6	25.2	3,736	–	53/1 1.7	1.5	0.5
Oct.	414,809	15.9	28.4	4,348	–	48/8.9	1.5	0.5
Nov.	4 12,826	15.1	30.3	4,557	–	3913.9	1.5	0.2
Dec.	411.919	14.7	30.3	4.670	–	3511.7	2.0	0.2
1989								
January	411,287	14.4	32.4	4,760	–	3511.7	3.1	0.5
Feb.	409.965	13.8	32.4	4.940	–	33/0	1.5	1.1
March	404,965	13.1	34.9	5.152	–	3813.3	1.5	0.2
April	404.093	12.0	37.8	5.612	–	45/7.2		

** 205,3 15 fish released on 30 September.

Release

The larger fish were released on 30 September 1988 and were 1 l/lb. The small fish were released 5 April 1989 at 15/lb, through a system of pipes that led directly to the river.

WILLAMETTE HATCHERY

Adult Spawners

Adult spring chinook salmon spawners (Willamette stock) arrived at the Dexter, Oregon holding ponds from the first week of June to the first week of September 1987. Adults were trucked to the hatchery from Dexter (approximately 30 miles) and held in a dirt holding pond of irregular shape (approximately 250 x 20 x 2-ft deep; 10,000 cu ft). Inflowing water (2,500 - 2,800 cfs) was from Salmon Creek and averaged from 12 to 14° C (54 to 57° F) during the holding period. From a total of 1,758 adults (679 males, 1,079 females), 509 (29%) suffered prespawning mortality (186 males, 323 females). Adults were injected with oxytetracycline at the time of collection at Dexter (0.5 ml/16 lbs).

Spawning began the first week of September (1987) and eggs were taken on the dates shown below:

Date of egg take:	9/7	9/15	9/18	9/22	9/25	9/28	10/1	10/5	Total
Females spawned:	143	201	95	165	50	40	19	9	722

A total of 3,594,000 eggs were taken. Sperm from several males was pooled and used to fertilize the eggs.

No IHN was detected; however, low levels of BKD were observed in spawned adults. Some furunculosis. enteric red mouth, Ceratomvxa shasta, and low levels of BKD were found in the prespawning mortalities.

Eggs

Green eggs from early takes (9/7-9/1 8) were placed in baskets (25,000-26,000 eggs/basket), water hardened in Salmon Creek water, and placed in redwood troughs with inflowing water at about 12 gpm. Eggs from later takes (9/25-10/5) were placed in Heath uays with 9,000-10,000 eggs/unit and inflowing water at 5 gpm. Egg loss was 12.6%. Fish monitored in this study (April and May release groups) were from the later egg takes. Once the eggs were in their containers they were given a medicated bath for 10 minutes using a solution of Argentyne. Eggs were incubated in ambient water from Salmon Creek (average temperatures 3-14° C (37 - 58° F) during September 1987 to February 1988. At eye-up, eggs were shocked and picked. Hatching occurred from late December to late February.

Early Rearing

As eggs hatched, the fish were transferred to inside fiberglass tanks (Canadian) that measured 16 ft x 32 in x 21-in deep (54,000- 88,000 fish/tank at 1,221 - 1,308 fish/lb, unfed fry). Each tank received Salmon Creek water at 10-20 gpm, 3-7° C (38-45° F). First feeding occurred about 10 days after transfer to tanks. The delay in feeding was to help control internal fungus. After about 3 weeks in the fiberglass tanks, fish were transferred to outside raceways. Biodiet Starter #2 was used for initial feeding. Fry loss was 58,000 (1.8%). There were no treatments for disease during the early rearing period.

Raceway Rearing

Outside rearing ponds consisted of modified Burrow's ponds measuring 80 x 20 x 2.6-ft water depth (approximately 3,690 cu ft). No more than 350,000 fish were placed in a pond, with a maximum of 4,000 lbs/pond. Inflowing water came from Salmon Creek and ranged from 100 to 150 gpm initially, then up to 450 gpm as fish grew. Beginning in April 1988, fish were fed OMP pellets which ranged in size from 3/64 to 1/8 in as fish grew. Fish used in this study, which were released in April and May 1989, received

Biomoist (4 mm) from March until release. Fish were fed on demand until May 1988, then according to targeted sizes until release:

Month	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Target (fish/lb)	196	95-97	45	25	15	12	10.5	9.8	9.5	9.0	9.0

In September 1988, fish were tagged with coded-wire tags and divided into groups for later releases. Those monitored in this study were tagged on 1 and 2 September and were placed in a divided raceway with slightly over 22,000 fish in each half of the pond (ponds 21A, code 07-50-32; and pond 21 B, code 07-50-35). As part of the normal production plan, fish from earlier egg takes (7 and 15 September) were transferred to Dexter during April 1987 and released in November 1988.

Release

Some of the juveniles (one third of the production) of this brood year were released from Dexter on 14-15 November 1988. Most of the remaining two thirds of the production was released on 6 March 1989, with subsequent releases of groups monitored in this study on 15 April (11.2/lb) and 4 May (10.0/lb). Fish were released at Pengra Boat Launch, below Dexter Dam in the Middle Fork of the Willamette River after trucking from the hatchery (about 30 miles).

Information on rearing densities, growth, temperatures, and food conversion are found in the following table:

Year & Month	Fish/ pond	Fish/lb	Wt (g)	Lbs fish/ pond	Water temp. (°F/°C)	Food conver. (food/ % gain)	Mon. (%)
1987							
Dec.	–				40.2/4.6		
1988							
January	–				39.7/4.3		
Feb.	–				40.8/4.9		
March	262.066	426	1.1	615	42.5/5.8	0.93	–
April	199.349	198	2.3	1,005	45.5f7.5	0.68	–
May	112,743	170	2.6	622	47.6/8.7	3.11	–
June	108.917	89	5.1	1,223	52.3/11.3	0.49	–
July	43,635	48	9.5	909	57.7/14.3	1.43	–
August	43.134	25	18.4	1,754	57.5/14.3	1.20	–
Sept. A	22.63 1	21	21.6	1,078	52.5/11.4	1.15	<0.01
Sept. B	22,892	21	21.6	1,090			co.01
Oct. A	22,628	18.6	24.4	1,782	50.0/10.0	1.43	<0.01
Oct. B	22.891	19.1	23.86	1,802		–	co.01
Nov. A	22,626	16.8	27.0	1.337	44.0/6.7		0.04
Nov. B	22.890	11.8	38.5	1,940			0.02
Dec. A	22,617	15.0	30.3	1,508	39.9/4.3	1.32	0.02
Dec. B	22,886	16.0	28.4	1,430			0.04
1989							
Jan. A	22.612	14.2	32.0	1.592	39.7/4.3	2.38	<0.01
Jan. B	22,878	14.7	30.9	1,556			<0.01
Feb. A	22.610	14.0	32.4	1.615	37.8/3.2	3.05	0.07
Feb. B	22,877	13.0	34.9	1,760			0.02
Mar. A	22,545	11.4	39.8	1,978	41.7/5.4	2.50	
Mar. B	22,873	12.6	36.0	1,815			
April B	22,849	10.0	45.4	2,284	45.0f7.2	2.40	–

A = pond 21A, April release; B = pond 21 B, May release.
Pond volume = 3,690 cu ft for production fish; pond volume = 1,835 cu ft in 21A and 21B.

COMMENTS

Tables 1 and 2 compare average monthly weights (fish/lb and grams) of brood year 1987 production spring chinook salmon at the four monitored hatcheries during most of the rearing time. Figure 1 compares growth curves, showing some important differences in rates of growth, some of which are due to varying temperature patterns (Fig. 2, Tables 3 and 4). It is interesting that spring chinook salmon at Willammette Hatchery begin as the smallest fish in the four hatcheries. Nevertheless, they overtook in size fish at Leavenworth and Dworshak by June and July 1988, and Warm Springs by January 1989. It must be remembered, however, that Warm Springs released their larger fish the previous September.

Table l.-- Number of fish/lb during the rearing period at the four hatcheries monitored in the smolt quality assessment.

Date		Number of fish/lb			
		Dworshak	Leavenworth	Willamette	Warm Springs
1987	Dec	--	674	--	532
1988	Jan	--	396	--	--
	Feb	--	241	--	--
	Mar	--	122	426	190
	Apr	168	95	198	105
	May	116	76	170	53
	Jun	76.3	58	89	29
	Jul	60.5	43	48	21
	Aug	44.4	33	25	18
	Sep	33.9	27	21	18”
	Oct	26.8	24	19	16
	Nov	23.3	25	17	15
	Dec	21.5	26	16	15
1989	Jan	19.6	25	14	14
	Feb	19.9	25	13	14
	Mar	19.0	22	12	13
	Apr	--	20	10	12

a Fish were graded and larger ones were released on 30 September.

Table 2. -- Weight (g) of fish during the rearing period at the four hatcheries monitored in the smolt quality assessment.

Date		Weight of fish (g)			
		Dworshak	Leavenworth	Willamette	Warm Springs
1987	Dec	--	0.67	--	0.9
1988	Jan	--	1.15	--	
	Feb	--	1.88	--	
	Mar	--	3.72	1.1	2.4
	Apr	2.7	4.78	2.3	4.3
	May	3.9	5.97	2.7	8.6
	Jun	6.0	7.83	5.1	15.7
	Jul	7.5	10.56	9.5	21.6
	Aug	10.2	13.76	18.4	25.2
	Sep	13.4	16.81	21.6	25.2[a]
	Oct	16.9	18.92	23.9	28.4
	Nov	19.5	18.16	26.7	30.3
	Dec	21.1	17.46	28.4	30.3
1989	Jan	23.2	18.16	32.4	32.4
	Feb	22.8	18.16	34.9	32.4
	Mar	23.9	20.64	37.8	34.9
	Apr	--	22.7	45.4	37.8

[a]Fish were graded and larger ones were released on 30 September.

Figure 1. -- Growth curves for spring chinook salmon reared at Dworshak, Leavenworth. Warm Springs, and Willamette Hatcheries.

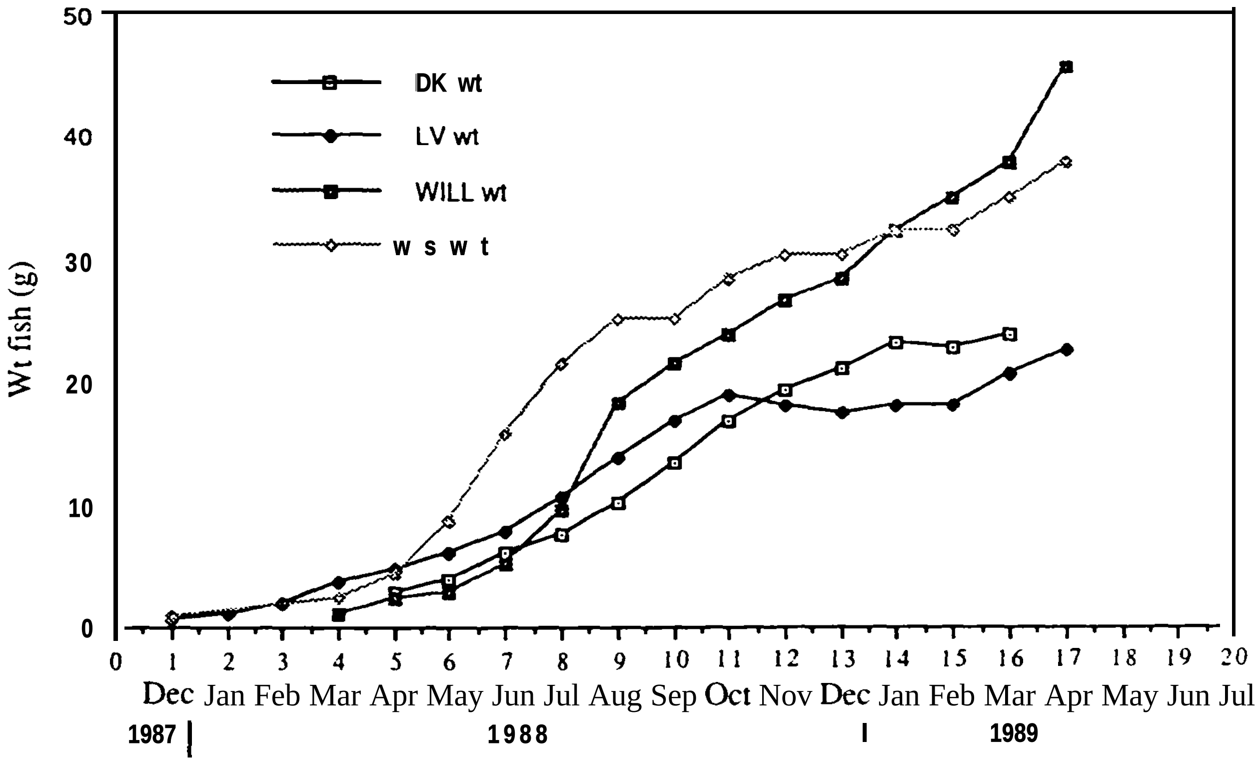


Figure 2. -- Temperature curves for rearing waters of brood year 1987 spring chinook salmon at Dworshsk, Leavenworth, Warm Springs, and Willamette Hatcheries.

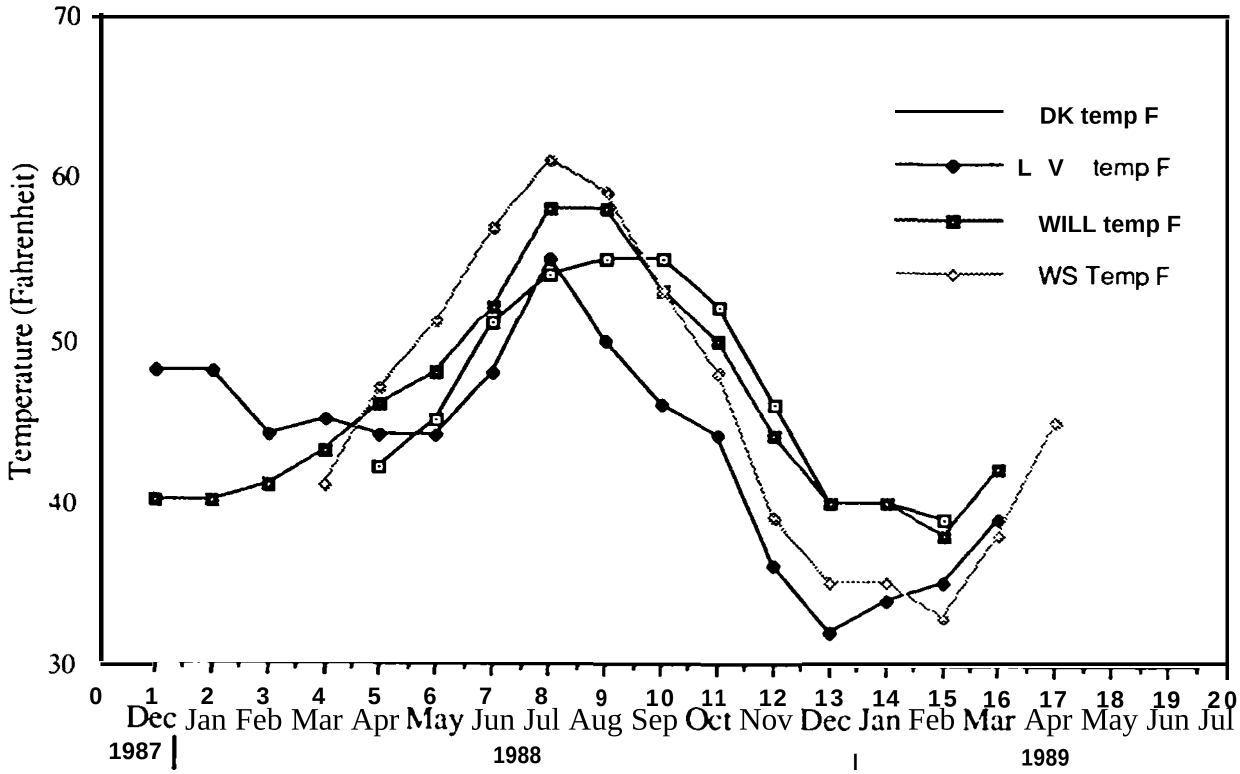


Table 3. -- Temperature (^oF) during the rearing period at the four hatcheries monitored in the smolt quality assessment.

Date		Dworshak	Leavenworth	Willamette	Warm Springs
1987	Dec	--	48	40	
1988	Jan	--	48	40	
	Feb	--	44	41	--
	Mar	--	45	43	41
	Apr	42	44	46	47
	May	45	44	38	51
	Jun	51	48	52	57
	Jul	54	55	58	61
	Aug	55	50	58	59
	Sep	55	46	53	53
	Oct	52	44	50	48
	Nov	46	36	44	39
	Dec	40	32	40	35
1989	Jan	40	33	40	35
	Feb	39	35	38	33
	Mar	--	39	42	38
	Apr	--			45

Table 4. -- Temperature (°C) during the rearing period at the four hatcheries monitored in the smolt quality assessment.

Date		Dworshak	Leavenworth	Willamette	Warm Springs
1987	Dec		8.8	4.4	
1988	Jan		8.8	4.4	
	Feb	--	6.5	5.0	--
	Mar	--	7.2	6.1	5.0
	Apr	5.6	6.7	7.9	8.3
	May	7.2	6.7	9.0	10.6
	Jun	10.6	9.0	11.1	13.9
	Jul	12.2	12.6	l-I.4	16.1
	Aug	12.8	9.9	14.4	15.0
	Sep	12.8	7.9	11.7	11.7
	Oct	11.1	6.8	10.0	8.9
	Nov	7.8	2.1	6.7	3.3
	Dec	4.4	0.2	4.4	1.7
1989	Jan	4.4	1.1	4.4	1.7
	Feb	3.9	1.8	3.3	0
	Mar	--	3.9	5.6	3.3
	Apr			--	7.2